TRAINING MANUAL

- AGRICULTURAL PRODUCTION AND PROCESSING -

PRESERVATION, PROCESSING AND PACKING OF FRUITS AND VEGETABLES

COLEACP

This training manual was produced and designed by the Training, Information and Communication services of COLEACP.

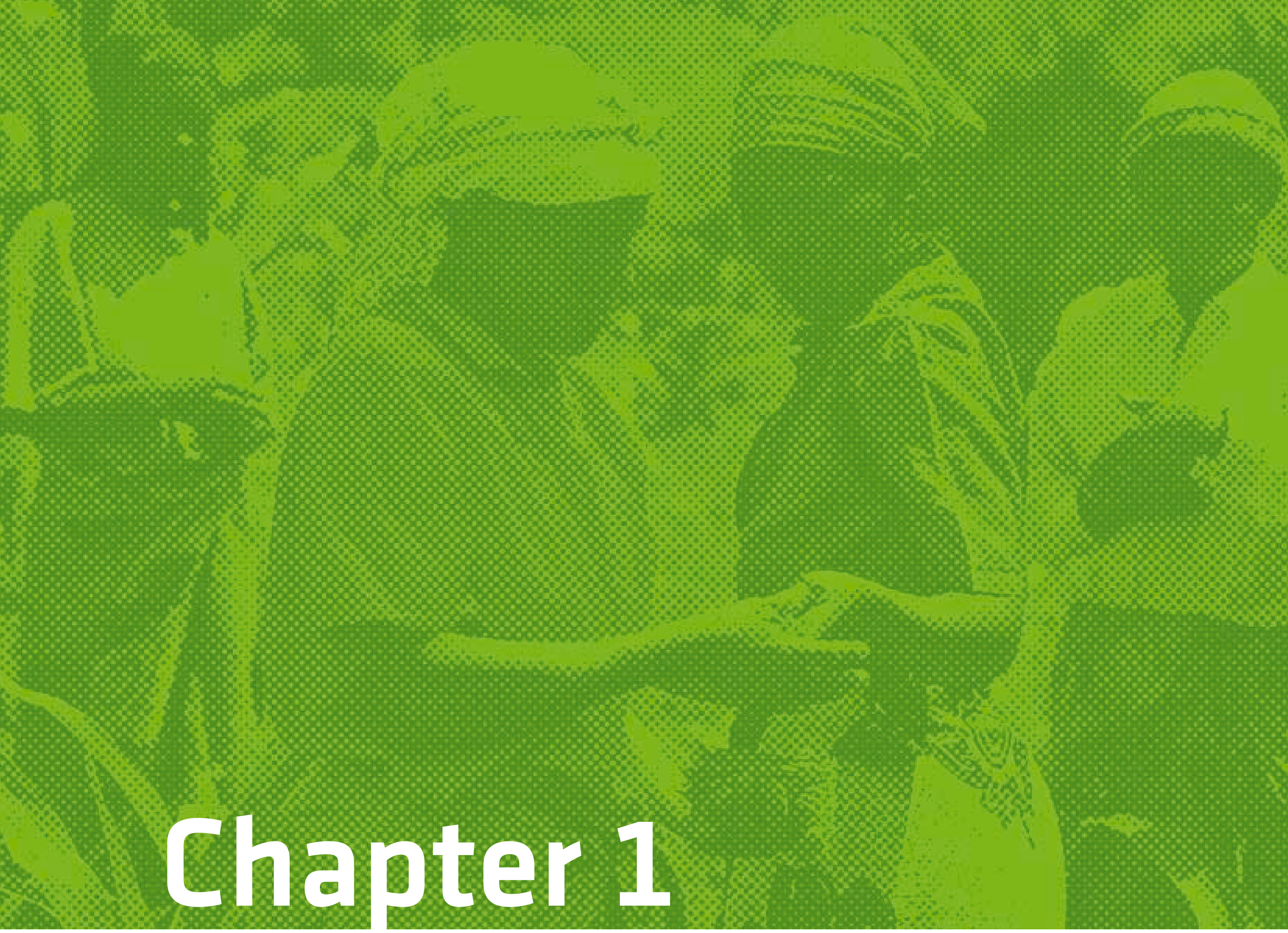
This background information document has been prepared by the COLEACP as part of co-operation programmes funded by the European Union (European Development Fund – EDF), the Organisation of African, Caribbean and Pacific States (OACPS), the Agence Française de Développement (AFD) and the Standards and Trade Development Facility (STDF).

COLEACP implements two intra-ACP Fit For Market programmes. The Fit For Market programme, co-funded between the EU and the AFD, now in its fifth year, aims to strengthen the competitiveness and sustainability of the African, Caribbean and Pacific (ACP) horticultural sector, primarily for the private sector.

Fit For Market SPS began in January 2019 and focuses on strengthening the sanitary and phytosanitary (SPS) systems of the ACP horticultural sector, primarily for the public sector.

Both programmes form part of the intra-ACP indicative programme (2014-2020) ofcooperation between the EU and the OACPS.

PRESERVATION, PROCESSING AND PACKING OF FRUITS AND VEGETABLES



Chapter 1

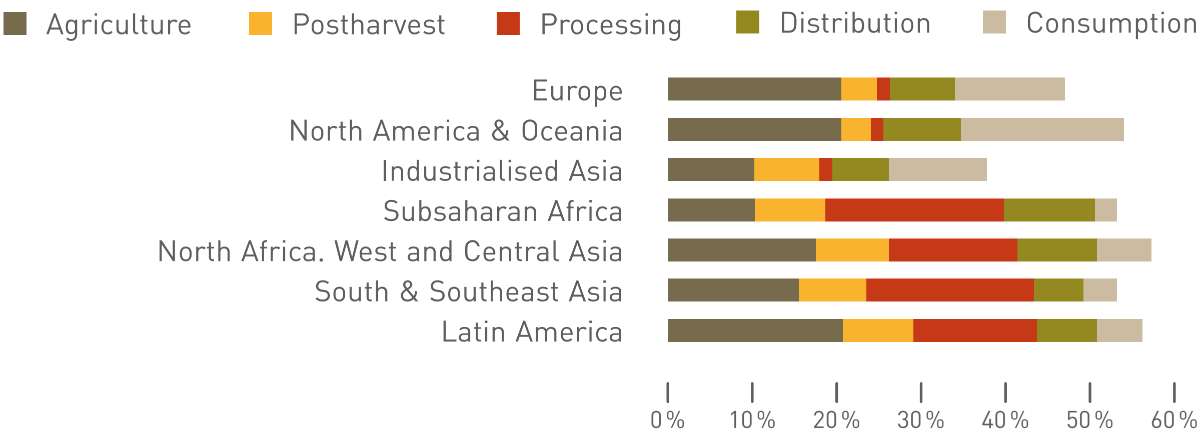
Food processing: challenges and limitations in ACP countries

1.1. INTRODUCTION

1.1.1. Intolerable losses

Without processing, a huge amount of food (sometimes up to 90%) is lost after it is harvested and before it can be eaten. Although losses incurred during the production period are estimated to be 30% overall (largely due to weeds, diseases and pests), **post-harvest losses can be even higher**, often caused by inadequate warehouses which allow humidity, parasitic fungi, vermin and insects to wreak havoc, but also by a lack of sufficient demand at times of overabundance caused by **production peaks** (especially, for instance, when the same variety is imposed on a given region, leading to a sudden excess of products, which cannot be used). For the farmer, however, post-harvest losses are even more frustrating and economically damaging than those incurred during production because wasting a proportion of your harvest means losing everything you invested in terms of labour, seed, fertiliser, water, phytosanitary products, and so on.

Fruits and vegetables, as well as roots and tubers, have the highest loss rate of all food products; thus almost half of the fruits and vegetables produced are lost.



Fruit and vegetables spoil extremely easily. Currently, around the world, up to 23% of the most perishable fruit and vegetables are lost in the agro-food chain because they spoil as a result of rotting, drying out or damage caused by mechanical processes used during harvesting, packing and transport, or by the mode of transport itself. These losses are estimated to **exceed 40 to 50% in tropical and subtropical regions** (FAO manual, 2004 citing a study published in 1995). Losses are also incurred when they are stored and prepared both at home and in restaurants. Moreover, in many ACP countries, only a limited amount of products made from fruit and vegetables is sold in local markets or exported due to the lack of equipment and infrastructure necessary.

However, according to the FAO, post-harvest losses remain difficult to measure due to a lack of reliable data but **they are widely thought to be one of the most significant challenges** facing agriculture and the agro-food industry in Africa.

For instance, the FAO estimates that in Nigeria between 50 and 60% of root vegetables and tubers are lost, along with over 50% of fruit and vegetables due to poor storage conditions. According to WECARD (2016)[1], production losses remain high (between 15 and 40%) and are due in places to a lack of local food processing facilities and suitable storage. Tomatoes and mangoes are good examples of products which are severely affected by post-harvest losses. It is therefore not surprising that there are many storage and processing options available for such products (dried, candied, preserved in oil, purees, jams, juices, etc.).

Such high and recurrent losses are intolerable given the shortage of food across the African continent, the arduous nature of agricultural work and the poverty endured by many households. It is very hard for a farmer to accept that his harvest has been lost. To limit such high losses, various measures need to be adopted to reduce them as much as possible during the harvesting, handling, storage, packing and processing of fresh fruit and vegetables into products which are more suited to preservation. To reduce these losses and turn the challenges of sporadic overproduction into benefits for local populations, it is essential to **develop methods and companies able to process** perishable products such as fruit and vegetables.

1 WECARD "Note d'information sur les politiques et stratégies de transformation alimentaire des produits agricoles en Afrique de l'Ouest et du Centre". The West and Central African Council for Agricultural Research and Development (WECARD) is an international not-for-profit association bringing together national agricultural research bodies from 22 countries in West and Central Africa.

1.1.2. Food processing: an age-old but undervalued practice

Food processing is as old as the human species itself. Specialists in food and sociology have argued that it was practised along with hunting, picking, foraging and fishing for thousands of years. Food processing did not begin, as we used to think, when settlements formed around crop and livestock farming about 11,500 years ago.

Each one of the world's regions, depending on their agroclimatic, economic and social conditions, gradually developed its own traditional methods for processing its produce to create new foodstuffs and form eating habits specific to a given region or social group. Therefore, right at the dawn of humanity, **the basic principles of food processing were already known and the techniques used are similar** to those which are still practised today, including cooking, drying, smoking, salting, cold storage, sugar preservation and fermentation. It would seem that the modern era has come up with very little aside from better equipment and awareness of food hygiene.

Thanks to food processing (such as drying or salting), producers are able to **improve the shelf-life** of their products, sometimes for long periods (several months) making them less vulnerable to insects and rodents, as is the case for grain reserves stored in granaries.

Food processing also **enhances the variety of people's diets** by supplying vitamins and minerals which are not found in stored grains. It also provides sufficient food reserves, in terms of quality and quantity, to tide people over during lean periods. For some foods, **processing is an essential step required to make them edible** (e.g. retting of cassava roots removes hydrocyanic acid making them non-toxic) **or easier to digest.**

From artisanal retting of cassava...

to cassava flour crepes for gluten-free diets

Food processing has other advantages too. It helps to reduce wastage of perishable foods (such as fruit and vegetables) during periods of seasonal over-production and enhances them too. Food processing can be used to reduce poverty in rural areas by creating jobs and generating additional income. Indeed, fruit and vegetables are raw materials which are often plentiful in the region in midseason. As a result, acquiring them simply requires basic investment in rudimentary processing technology, which is used in rural areas. With very little start-up capital (e.g. € 1,000), a group of women or a producer can get started in food processing by using kitchen utensils available at the local market and gradually develop from there. Turning mangoes into mango chips provides added value compared to perishable mango.

1.1.3. From artisanal production to agribusiness[2]

Over the last 20 years, trade in horticultural products from ACP countries to Europe has grown steadily. The ACP countries, and Africa above all, are seen as gold mines for the agro-food sector. Indeed, Africa is among the continents which has the most space available (1,242,600 hectares of agricultural land). It is encouraging to see that agricultural performance has recently been improving in Africa. However, most of the production surplus comes from an increase in the areas farmed rather than improved productivity or an increased use of modern inputs.

Although the growth rates for agricultural productivity in Africa are generally disappointing, 13 countries in the region have nonetheless doubled their production in two decades since the 1980s, and some started from very low bases. Countries where smallholdings are in the majority, such as Burkina Faso, Ghana, Mali and Niger, are among the best performing. Countries where small-scale agriculture is less significant are achieving less impressive results (World Bank)[3]. According to research by the World Bank, over 50% of fertile land is in Sub-Saharan Africa. Africa is spoken of as the world's breadbasket for the future.

However, due to the lack of expertise and poor crop management, Africa has made little progress in terms of harvests. **African countries produce huge quantities, but only a small proportion of food is sent to local agro-food factories.**

Until now, the lack of food processing infrastructure has forced African countries to export its raw materials for processing, and then import them back to be sold on the African market. This represents a significant economic loss for those countries as well as a waste of time.

2 Also see P. Jacquet, R.K. Pachauri & L. Tubiana, *Regards sur la Terre – Agriculture et développement économique en Afrique: les termes du débat*, Paris, Armand Colin, 2012.

3 World Bank, "Agriculture et industrie agro-alimentaire en Afrique: favoriser un développement inclusif".

The biggest multinationals and SMEs operating in Africa are now aiming to produce and process food locally in order to meet the ever increasing demand much quicker. Indeed, professionals in the agro-food sector point out that local processing of agricultural produce into foodstuffs holds **significant potential** in terms of both rural and urban jobs and the creation of economic and social value. The **demand for processed food products from African consumers is growing** as a result of increasingly modern lifestyles and rising purchasing power among some sectors of the population.

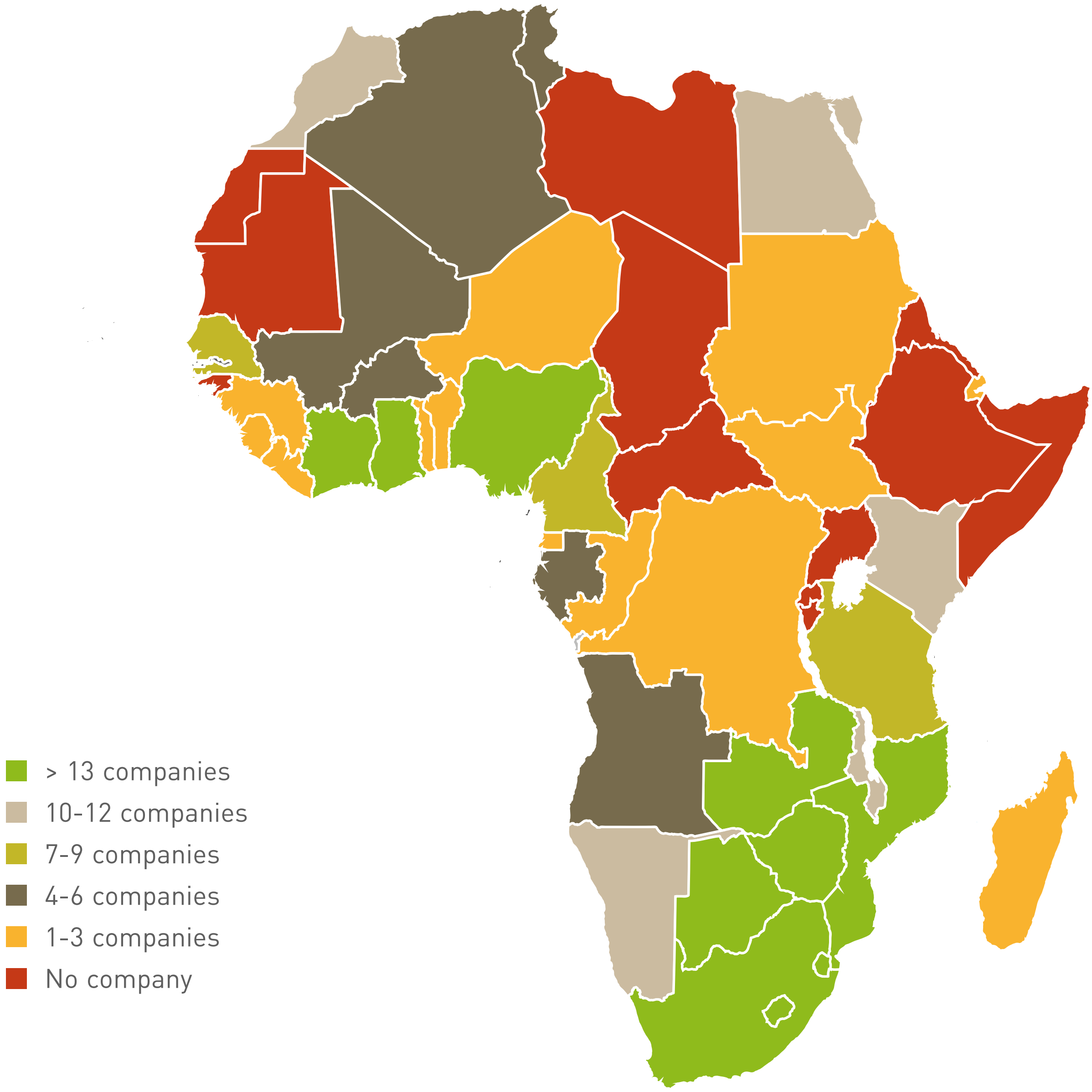
Given this potential for growth and increasing consumer demand, multinationals (e.g. Nestlé, Danone, Unilever, etc.) are ramping up their investment in Africa. This is why the agro-food sector has been developing over recent years. Nevertheless, feelings of triumphalism should be tempered. In Côte d'Ivoire, for instance, despite the pro-active and voluntary support from the political authorities, agribusiness accounts for just 3% of GDP and the local economy remains heavily dependent on the primary agricultural sector.

For now, only South Africa has the agro-food and commercial capacity required. The obstacles to development in this sector are explained by the **shortage of capacity and human skills. African businesses do not have enough experience in terms of management and development of companies** operating in the agro-food sector.

It is however **essential to check every link in the value chain** to ensure the success of agribusiness in ACP countries. This is certainly the case for the first link in the chain: production. Too often, when fruit trees and vegetables are planted around huts, the plant material is not carefully selected or optimal in terms of yield or quality. Trees are not regularly maintained, maintenance and regenerative pruning is not carried out, organic or chemical fertilisers are not regularly used and there is no regular phytosanitary monitoring. Agronomic monitoring is not carried out on plantations. Consequently, poor quality fruit will inevitably result in second-rate processed products.

If the processing sector wants to expand to an industrial scale, horticultural production must follow suit in terms of quality and quantities available.

1.1.4. Extremely varied situations from one country to another



OECD (2007): "Répartition des 500 premières entreprises agro-alimentaires en Afrique"

Overall, the situations observed today **vary wildly from one country to another** based mainly on:

- The structure of the sector,
- Types of production,
- Demand on the local market, largely related to consumption patterns and eating habits,
- Distance from the markets,
- Local transport or storage conditions,
- Presence of innovation and support centres for the agro-food sector,
- The willingness of local authorities to offer support.

In general, the processing equipment in most of the countries in question is often rudimentary, dilapidated or obsolete, largely unable to provide satisfactory levels of quality for increasingly urban consumers who have grown used to higher standards. As a result, after produce is harvested, **the sale of fresh products on a local market and traditional, artisanal processing remain the norm.** Although this is of course accompanied by occasional technological improvements, they rarely become widespread across the country.

1.2. WHAT IS THE GENERAL CONTEXT OF THE AGRO-FOOD SECTOR IN ACP COUNTRIES AND WHAT ARE ITS MAIN CHALLENGES?

1.2.1. The major challengers for the processing industry to overcome

The most significant challenges to overcome are[4]:

a. **Infrastructure** – For the expansion of the agro-food sector to be effective across the African continent, it is essential to implement suitable infrastructure. Specifically, this includes infrastructure for production (e.g. irrigation, water reserves, developments for access to land, etc.) and transport (roads in good condition), sorting and storage infrastructure, markets with good hygiene standards, infrastructure for communication and broadcasting of information, access to drinking water, consistent electricity supply, and so on. Indeed, the lack of a decent rural road network and information on the prices of various foodstuffs significantly limits farmers' ability to access the markets and negatively affects their income. Post-harvest losses incurred are therefore considerable. The funding of the agro-food sector also needs to be improved. Foreign direct investment in African agriculture amounts to 7%, which pales in comparison with Asia (78%).

b. **Access to energy**[5] – Without energy, it is impossible to develop an agribusiness sector which requires heat for drying or cooking, steam, electricity for machines and cold storage, fuel for transport, and so on. Without affordable energy, it is impossible to put competitive products on the market. In addition, without investment in renewable energy, it is impossible to compete with imported products in terms of their carbon footprint (e.g.: products made in countries with plenty of nuclear power stations have a much smaller carbon footprint than those from countries with fossil fuel power stations). Although Africa has plentiful sources of energy (19% of the global production of fossil fuels and an enormous but underexploited potential for renewable energy), it only consumes 3.2% of the world's primary energy, which is the lowest consumption per capita of any continent. In 2014, half of Africa's population (1.2bn people) did not yet have access to electricity, with biomass providing basic energy for cooking. Considerable infrastructure development is therefore

4 See AfrikaTech, "État des lieux du secteur agro-alimentaire en Afrique en 2017", www.afrikatech.com/fr/.

5 R. Cantoni & M. Musso, "L'énergie en Afrique: les faits et les chiffres. Introduction", *Afrique contemporaine*, 2017/1-2, n° 261-262, pp. 9-23.

absolutely vital. Investment in this sector could be pivotal in improving agribusiness activities. Poor energy infrastructure is consistently identified as one of the main reasons for the lack of investment in industrial sectors but the implementation of energy infrastructure projects has also aggravated the problem of corruption (Brookings Institute, 2016)[6].

c. **Land ownership** – Many farmers are not able to increase their production. Indeed, access to land is extremely limited. It is essential to reform the current land distribution models used in Africa. Both governments and investors need to implement rules to protect the environment in order to reduce the risks related to agro-food investment. Specifically, it is a case of investing in the purchase of land on a large scale.

d. **ITC** – The role of information technology and communication is vital for the development of the agro-food industry. This technology needs to be involved at every stage of the process: before growing (selecting land, access to credit), during cultivation and harvest (water management, land preparation, etc.), and after the harvest (transport, packaging, marketing, etc.). The importance of ICT in the agro-food sector has been grasped by Kenya and Zimbabwe. Thanks to ICT, farmers have been able to increase their yield and their income. Well-judged use of ICT can help to make savings, increase incomes and boost the profitability of agro-food companies of any size.

e. **Investments** – African companies and investors need to seize the opportunity offered by the agro-food sector to realise its full potential. To do this, agriculture should be seen as a commercial activity and inspiration should be drawn from best practices elsewhere. It is important to link up industrial capacity for manufacturing and processing with agricultural production. Moreover, losses incurred at every stage of the process (farm, storage, transport, retail, etc.) must be eliminated. Thanks to their funding, investors will be able to realise Africa's full potential in the agro-food industry. However, cooperation between the financial and agricultural sectors is fundamental. Investment challenges are directly related to **the business environment.** Indeed, agro-food companies are often faced with growing investment requirements. Although investments are often **material** in nature (acquisition of new, versatile and better performing equipment), they may also bring **intangible** benefits. These companies often have to make do with poorly qualified staff and incur high costs for promotion and advertising. Access to funding is a significant challenge and the informal nature of the sector makes things harder still.

6 It is important to note that of the various agro-food sectors, the fruit and vegetable sector is one of the least energy-intensive sectors (accounting for around 5% of the energy consumed by the agro-food industry overall).

f. **Commercial challenges** – These are immense due to competition, and sometimes unfair competition, from imported products. Agro-food industries in ACP countries need to conquer emerging markets and, above all, maintain the internal market. To do this, they need certain pre-requisites which are not necessarily featured on SME/SMI dashboards. They need to pay more heed to new consumer demands in terms of safety and nutrition and strive to increase the processing of products to offer consumers foods with high added value.

g. **The challenge of public policies and investment strategies** – This is the challenge of linking up the growth of agribusinesses with the development of equipment suppliers and agro-food services (consultancy, training, distribution, marketing, etc.) where there is also potential for growth and employment, while bearing in mind the importance of food security. Indeed, it is critical to ensure that the poorest families can feed themselves properly at a reasonable cost.

h. **The challenge of research and development** – Agro-food businesses rely heavily on research and development to boost their competitiveness. However, they often need to import the majority of their equipment. When there is even the slightest fault, parts need to be sent from Europe, leading to huge financial losses for small businesses. Pilot centres (e.g. CTA in Senegal) help to transfer technology, offering considerable benefits.

1.2.2. SWOT Analysis

Using a SWOT analysis carried out by WECARD[7] in 2016, we have attempted to update the outlook and identify the **strengths of the agro-food sector and the weaknesses hindering its development, as well as the opportunities and threats it is faced with.**

1.2.2.1. What are the strengths?

The strengths of the policies and strategies for the processing of agricultural products include:

- The management of seasonal food shortages,
- The promotion of labour-intensive small businesses and the support of operators looking to invest in agribusiness,
- The simplification of procedures for starting a business,
- An improving business environment,
- The dialogue between the state and the private sector regarding a medium-term sector-by-sector development plan,
- The implementation of development plans by businesses processing local products and by companies in the animal industries sub-sector.

7 WECARD "Note d'information sur les politiques et stratégies de transformation alimentaire des produits agricoles en Afrique de l'Ouest et du Centre. SWOT: Forces / Faiblesses / Opportunités / Menaces", 2016.

1.2.2.2. What limitations are holding the sector back?

Unfortunately, the weaknesses are many and varied, making it challenging to find effective solutions and implement them swiftly. These include:

- Restrictive tax law and administration,
- Land tenure problems,
- Low level of professionalisation among operators (family agriculture),
- Poor competitiveness of processing facilities,
- Poor diversification of products,
- Dispersion of farms,
- Poor reactivity of agricultural production to market demands,
- The growing liberalisation of national economies and the disengagement of the state,
- High levels of post-harvest losses of certain extremely perishable products, such as bananas and tomatoes,
- Scarce funding opportunities,
- Distant markets,
- Difficulty in accessing and becoming proficient with technology,
- Difficulty in accessing and/or the cost of energy,
- Difficulty in procuring suitable raw materials, equipment and packaging,
- Poor knowledge of the markets and the opportunities created by bilateral and multilateral agreements,
- A lack of quality policies and not enough structures for checking and certifying standards,
- Price instability and inconsistency in the supply of raw materials,
- Difficulty in accessing financing,
- Poor and dilapidated small-scale processing equipment,
- Poor performance of artisanal processing methods,
- Lack of technology suited to the realities on the ground,
- Barriers to product loops between neighbouring countries.

1.2.2.3. What opportunities are there to be seized and what are the strategies?

- The increase in the demand for food following demographic growth, especially for products which are cheaper than imported products (although this is relative for certain products).
- Greater agricultural productivity by using new agricultural and agro-pastoral technology.
- The willingness of ACP countries to develop the agricultural technology sector to provide people with healthy and high-quality food, especially through the promotion of local products.
- A potential and growing demand for processed local products (desire to showcase these products on the market).
- The integration of sub-regional markets (making trade between regions easier).
- The age-old experience and expertise of local populations: promote high-quality artisanal products (competitive advantage over imported products).
- The development of qualification pathways for managers and workers.
- The creation of thousands of jobs in rural areas by the installation and monitoring of plants for processing and preserving local products.
- The environmental benefit of food processing: no produce is wasted, it usually provides very good yields over a short time period, and by-products can be reused (energy, compost, oils, livestock feed, etc.)

1.2.2.4. What are the threats for the sector?

- The state disengaging from public companies.
- The problems of energy, quality and access to water (availability and cost).
- The lack of suitable credit for the sector.
- Inadequate transport and storage infrastructure.
- The reduction in or lack of freight options.
- Stricter phytosanitary requirements (access to EU market).
- Inadequate "annual supervisory plans" (shortcomings in the analysis of sanitary and phytosanitary risks, insufficient sampling to ensure the control of sanitary and phytosanitary risks due to the cost of official checks or the inability to carry them out).
- The lack of basic infrastructure for ensuring effective and comprehensive official oversight (diagnostic laboratory, laboratories for analysing various contaminants).
- The lack of sufficient numbers of qualified staff for monitoring and certifying products.
- The difficulty in accessing information for professionals in the sector (e.g.: lack of systematic regulatory oversight, lack of equipment)
- Other sources of competition (dumping).

1.3. PRESERVATION, PROCESSING, PACKING

1.3.1. The six product categories

There are various methods for processing and preserving food, from unprocessed raw foodstuffs to products in cutting-edge packaging. These different methods offer advantages and disadvantages, such as, for instance, whether the cold chain needs maintaining or whether they are detrimental to the nutritional quality of the food. Preparation and packing processes are set out in detail in the following chapters of this manual.

Experts in the sector have identified **six main product categories**.

1.3.1.1. Category 1: fresh products

These are fresh agricultural products in the same state as when they were harvested. They may be washed, sliced, trimmed, etc. preserved at room temperature or refrigerated and are perishable. Depending on the products and how mature they are when harvested, they can last for a few days to a few weeks at room temperature or in the fridge. The "use by" date[8] is relatively short for these products.

1.3.1.2. Category 2: pasteurised or sterilised products (jars, Tetra Briks, tins)

These are products which are treated by heat, pasteurisation or sterilisation and preserved in sealed packaging (metal, glass or other). Destruction of certain vitamins, denaturation of proteins, softening of fibres, and occasionally inversion of sucrose. Preservation at room temperature is lengthened to 2 to 5 years (Date of Minimum Durability[9]) in the correct conditions (e.g. jam jars).

1.3.1.3. Category 3: frozen and quick-frozen products

These are products which are cooled by freezing or quick freezing. Cold temperatures allows food to be preserved for a shorter time than products in category 2. Products can be preserved for several months at a temperature, which must always stay:

- Below -12°C for frozen products (slower method)
- Below -18°C for quick frozen products (faster method)

Texture change. Loss of micronutrients in the event of slow thawing. Obtaining a date of minimum durability (of several months). Maintaining the cold chain is essential. Products should be thawed in a fridge or can be cooked straight away.

8 A "use by" date is applied to perishable food which, after a short period, could pose an immediate danger to the consumer's health (product safety). This date can be found on the food packaging, preceded by the wording "Use by…". This "use by" date can be determined either by the producer or by the regulations in force for some specific products.

9 Date of Minimum Durability replaced the "best before" date in 2015 (refers to the quality of the product and not safety of the consumer). On packaging, the "best before" date is provided in the following way: "Best before…" followed by a day, month and year for products with a durability under three months, or "best before end…" followed either by a month and a year for products with a durability between 3 and 18 months, or by just a year for products with a durability over 18 months.

1.3.1.4. Category 4: raw ready-to-use plant products (peeled, chopped, trimmed) which are packaged in a modified atmosphere

These products (salads and "fresh" vegetables, grated carrot, pre-chopped vegetables, pre-cut potato chips) are packaged in an ambient or modified atmosphere, or vacuum packed, in a bag or container. Either the product is packaged in a controlled atmosphere, which involves increasing the proportion of carbon dioxide and lowering the level of oxygen to slow down the development of certain micro-organisms, or it is packaged in a vacuum which prevents the development of all micro-organisms. The micro-organisms become dormant, but other alterations are also slowed down. If the cold chain is properly maintained, products in category 4 can be preserved for 5 to 10 days maximum in a fridge between 0 and +4°C. Maintaining the cold chain is essential. They can be used for the fast preparation of salads, for instance. These products must carry a "use by" date.

1.3.1.5. Category 5: agricultural products which are vacuum cooked, pasteurised or sterilised and are ready for use, preserved through refrigeration.

These products are ready-to-use fruit and vegetables which have been sorted, pre-chopped, cooked or vacuum precooked. Once cooked or precooked, the products in category 5 are preserved by the same method as is used for products in category 4. The "use by" date depends on the packing method used (from a few days to a month). This type of product was developed in the 1980s to respond to new eating habits as lifestyles changed: people were cooking less and less and were simply heating things up more and more. Attention should be paid to the product/packaging combination. Plastic is usually used for packing in individual or multiple portions (catering industry). This category occupies a place in between sterilised and fresh products, with two sub-categories:

- *Category 5 of pasteurised vegetables*: Any plant-based food product which has been heat-treated at a temperature between 65 and 85°C at its centre, enabling it to be preserved for 21 or 42 days at ±2°C. It is essential to maintain the cold chain. These products must carry a "use by" date.
- *Category 5 of sterilised vegetables*: any plant-based food product which has been heat-treated according to a sterilisation schedule and at a temperature above 100°C (with the objective of destroying or inhibiting micro-organisms and their toxins), packaged in an airtight container which is impervious to microbial attacks. These products can be classed as conserves. They can be preserved for 6 months at room temperature.

1.3.1.6. Category 6: dehydrated and irradiated products for long-term preservation at room temperature.

The dehydrated products in category 6 can be preserved several months at room temperature and out of sunlight. The foods in category 6 can be dehydrated using various processes:

- Air drying by placing the product in front of a hot and dry current of air.
- Freeze drying: the product is frozen first, and then dried.

Category 6 also includes irradiated products.

1.3.2. Preservation, processing, packing: three intimately linked practices

The COLEACP manual will address these **three aspects, which are intimately linked**, and **sometimes confused** in publications written about them.

They involve a range of practices and methods which are carried out from the harvest to the distribution and sale of the product to the end user. The end user may be a neighbour (e.g. direct sale by the producer to the consumer) or live in a country far away with radically different standards and eating habits, which may have much higher quality expectations and requirements.

Moreover, these methods are used in both artisanal and industrial production. The "artisanal" label does not carry any negative connotations. In fact, these products are often deemed to be of higher quality (taste, flavour, local production using less standardised varieties offering better taste and higher nutritional quality). Other consumers may believe that artisanal and local products cannot reach the quality and safety standards of industrial products (especially when they are imported from Europe, Morocco or the USA). In this manual, we aim to present a production process on both an artisanal and an industrial scale for each product type (juices, purées, jams, frozen products, and so on). It should be noted that **the general production process is often based on the same principle**, even though the processes, procedures and equipment used differ in accordance with the volumes and level of risk involved.

Let us take a look at what the three areas addressed in this manual involve.

1.3.2.1. Preserving

Preserving food involves a range of treatment processes (including storage) which aim to preserve the taste and nutritional properties of products for as long as possible, as well as their texture, colour and edibility, as well as avoiding any food poisoning.

Preserving usually involves slowing down the oxidation of fats which causes food to turn rancid, and the autoxidation and autolysis by the enzymes in the cells of the food itself. It also aims to prevent the development of bacteria, fungi and other micro-organisms and combat pests, especially insects and rodents. Preserving food therefore focuses on all biotic factors (micro-organisms, animals, plant germination, etc.) and abiotic factors (light, oxygen, heat, irradiation, UV, etc.) which may harm the quality of the stored product.

Historically, different methods (drying, smoking, salting, storage in fruit cellars, granaries or buried containers, etc.) have been developed around the world to store food during periods of abundance and plenty in order to avoid scarcity and famine during lean periods, often known as the "hungry gap" (winter or dry season). However, among preserved products, dry foodstuffs (cereals, walnuts, hazelnuts, etc.) are in the overwhelming majority. Indeed, **some foods do not need any preservation methods to be used** and preserve themselves provided they are kept away from pests, while **others spoil very quickly.**

With the development of different modes of transport, trade between producing and consuming regions has reduced the need to preserve foods in some cases. However, in times of crisis, all countries want to have stocks in order to cope with a sudden shortage. The COVID-19 pandemic is a cruel reminder of what can happen in 2020 - producing regions which many rely on can also be affected by disasters of all kinds. Unfortunately, according to the FAO and WECARD, the almost total lack of infrastructure for preserving food leads to significant post-harvest losses: **around 30 to 45% for perishable foods, especially fruit and vegetables, which are the most delicate products and the most difficult to preserve in a good condition**, but also some subsistence crops, such as **bananas and yams**, which are basic foods for many people in Central and West Africa.

1.3.2.2. Processing

Since the key factor when preserving food is its **water content**, products have long been preserved by drying them out in the sun. At harvest time, fruit and vegetables are plentiful in the markets for a few weeks of the year, and then become scarce because they are perishable. On one hand, large quantities enter the market at the same time and as a result cannot all be sold, which leads to significant wastage, a drop in prices and a loss of earnings. On the other hand, in the off-season, the same products are scarce and are sold at high prices, but their production causes huge problems due to excessively high temperatures and water shortages. **There is consequently a fundamental necessity** (providing food) **and an economic interest** (increasing income) **in processing perishable products, such as fruit and vegetables, to preserve them and increase their value.**

In general, the staple foods of Central and West Africa remain cereals and tubers. However, some of these foods need to be processed in order to be accepted by consumers, eliminate certain toxins and improve their organoleptic and nutritional quality. Processing also helps to reduce post-harvest losses, increase shelf life, diversify forms of use and add value to the product. In addition, processing responds to the growing demand observed in some countries as a result of rapid urbanisation. According to WECARD, this demand has developed very quickly in and around some urban centres (Dakar, Bamako, Ouagadougou, etc.) and has been largely concentrated on local cereals (millet, sorghum, maize, fonio and cowpea). For other countries in humid or subhumid zones in Africa, traditional processing has focused on tubers (cassava, yams, etc.) and plantains. In various ACP countries (Cameroon, Congo, Côte d'Ivoire, Senegal, Madagascar, Mali, Mauritania, etc.), "pilot centres" have been set up to innovate and support the agro-food sectors, but much still remains to be done and many different opportunities to add value through processing are still waiting to be seized. Moreover, projects still need to be funded and carried out successfully.

Drying has **long been the main method for processing and preserving food.** It remains a widespread technique to this day across the world because almost all fruits, apart from citrus fruits, can be dried (dates, apricots, grapes, papaya, mango, etc.) As for vegetables, almost everything is well-suited to drying. Tomatoes, onions, cabbage, peppers, green beans, potatoes, chillies, aubergines and marrows are the products which are most frequently dried. **Drying thereby offers good income opportunities for rural families.** It allows surplus produce to be stored and enhanced so that it can be sold during lean periods. This is why it remains the most commonly used processing method in many parts of the world.

Alongside traditional dried fruit and vegetables, with the support of local authorities, **new companies are developing across the region** (often SMEs and micro-enterprises, which tend to be financially fragile and in their very early stages) **offering new local products using fruit and vegetables**, such as juice concentrates, fruit nectars, fruit purées, jellies, jams, tomato ketchups, metal tins or glass jars, and even frozen products. The growth of an industrial base in the agro-food sector has accompanied the **development of food transport** between areas of the same country and between countries in the same region, supporting the national market and building a very competitive regional market. Moreover, it has also been accompanied by the **development of products which meet increasingly strict quality standards** in the face of highly competitive foreign products.

1.3.2.3. Packing

The packing of fresh and processed products involves a set of operations which are carried out after the production or processing stage, as well as the type of packaging used and the marking of the products. Packing is a **key stage in processing and preserving** the products. It can be used to prevent damage to the products caused by impacts or crushing on pallets, avoid contamination from external sources, prevent or mitigate the effects of poor handling or storage conditions, and help significantly in identifying and tracking products through the marking and labelling of packaging.

As discussed in this manual, **the packing type, the materials used and the labelling** of fresh or processed fruit and vegetables are also inextricably linked factors. Indeed, choosing a packing process involves selecting a suitable type of food packaging and vice-versa in order to ensure the compatibility of the container and the product and the correct preservation of the packaged fruit and vegetables until they reach their destination market. This in turn requires accurate information to be stated on the product packaging.

1.4. CREATING A FOOD PROCESSING COMPANY

The aim of this manual is not to look at the details of creating a horticultural or agro-food company, but to highlight some of the basic principles.

> Other COLEACP manuals must be consulted to supplement your knowledge in the matter and help you to structure your project.

According to the FAO, for anyone looking to improve the processing of local products, especially by adopting better preparation and packing methods, there are two main options available:

- Improve the quality of processing, while remaining at a small-scale family production level (own consumption): the intervention logic simply aims to improve traditional practices to increase sanitary and nutritional quality at a very low investment cost;
- Develop the business and create a small company (a micro-enterprise, an SME, a cooperative, etc.): in this case, a series of questions need to be asked regarding the profitability and the sustainability of the company.

Creating and developing a company is **a complex process** which requires specific qualifications and skills (including the ability to take risks). It is a project which needs to be carefully planned or the start-up capital could be squandered. It requires preparation (market research, business plan) as well as knowledge of the products, methods and regulations involved. Like any project, creating a company requires a methodical step-by-step process to be taken.

When the goal is to create a company, **the main limitation is finding a market** to sell your products at a decent price. The key issues include managing the regular supply of raw materials (and possibly staff), understanding the different steps involved in food processing and production costs, and promoting and selling the products. Technical choices have an impact on the processing stages, the organisation of tasks and the investment in infrastructure. They also determine the most suitable equipment and its size with regard to the planned production volume.

1.4.1. The basic questions to ask

When setting out your project, you should ask yourself at least the following key questions.

1.4.1.1. What products can I process and in what form?

In theory, there are many possibilities offered by the various methods available. However, in practice, processors generally only have a (relatively) sound grasp of one type of technology, or two at most. Moreover, each type of processing requires specific equipment, tools, packaging and labelling.

Consequently, the choice is usually guided by the experience acquired on a small scale (family-scale processing).

Nevertheless, the decision to process products in a particular form will also depend on, for instance:

- the availability of equipment, ingredients, packaging;
- the availability of workers (some types of processing, such as fruit drying, require a larger workforce), especially qualified workers (e.g. welders, electricians, refrigeration technicians, engineers, etc.);
- the ability of potential transporters, distributors and buyers to maintain the cold chain;
- the regulatory requirements (e.g. hygiene measures imposed, standards regarding the premises);
- the size of the infrastructure and the space available;
- the planned storage time of the products;
- the planned volume of products;
- and so on.

1.4.1.2. What is the market?

Producing something is one thing, finding outlets for that product is quite another. To begin with, it is important to find a market which is large and profitable enough to cover costs and generate profits. This is a challenge everyone must overcome, from small traditional farms to artisanal companies.

The key questions to ask are:

- Which consumers will buy the products, where are they, and what distribution circuit can be used to reach them?
- What prices are they prepared to pay? Throughout the whole year?
- In what quantities will they buy the product? Will they purchase consistently throughout the year?
- Who are the competitors (e.g. alongside traditional dried fruit and vegetables, more attractive products manufactured in new and different ways are also being developed)?
- What prices are they being sold for? What are their products worth?
- How is the product consumed?
- What are the usual packing sizes and what type of packaging is used?
- How can my product be differentiated from the competition (e.g. organic or non-organic)?

1.4.1.3. What technical choices need to be made?

The technical choices to be made firstly involve the process itself, which depends on the type of product obtained after processing.

According to the size of the market, it is possible to anticipate desired sale volumes and the production volume as a result (total per month, per week).

Depending on the volume and type of product, the equipment is then selected according to:

- its purchase cost (or rather, the cost of staggered repayments) and the cost of using it (energy, maintenance, staff required, etc.);
- how long it takes to pay for itself (e.g.: according to the FAO manual, a "shell" dryer which costs 13,000 CFA francs can produce 3kg of dried onions per month, meaning that the equipment can be paid off after one year of use);
- its service life and maintenance costs;
- the availability of qualified tradespersons and companies nearby;
- successful processing experiences with this equipment in the region.

Taking the example of dried products - a particularly widespread processing method - the implementation of a drying system is heavily dependent on the climatic conditions of the region. In simple terms, three different situations can be outlined:

- In arid countries where temperatures are high and the air is dry, traditional drying remains the best compromise between quality and cost of production;
- In sunny regions with high humidity, direct and indirect solar dryers offer an attractive alternative;
- In climatic conditions which are not particularly suited to solar drying (rainy harvest period), using hybrid systems would seem to be the best solution.

These approaches should be adjusted to suit the local climatic conditions and periods of maturity of the fruit and vegetables being grown. For instance, in Senegal, the dry season from December to April offers optimal climatic conditions for solar drying, but mangoes reach maturity at the start of the rainy season around May. Solar drying becomes challenging and uncertain during that period.

1.4.1.4. How much should I invest?

The questions to be asked are:

- How can I fund my installation?
- Who can money be borrowed from? How will the loan be paid back?
- What is the production cost of the product?
- From what production volume does the investment become profitable?
- What margin will be taken?

All of these questions need to be answered, at least in part, before any activities begin. If the goal is simply own-consumption, the investment required is minimal. However, if there are commercial objectives, it is important to make decisions based on the market and try to anticipate profits. However, benefits are not always quantifiable. Purely economic considerations do not take into account improvements in product quality, reductions in labour time, increased adaptability and user-friendliness.

1.4.1.5. What risks can be predicted?

Setting up a company means accepting risks. It is therefore important to try and predict them in order to put suitable preventative measures in place.

Predictable risks can include:

- risks related to financing and the financial management of the company;
- risks related to errors in the technical choices made;
- risks related to a failure to comply with regulations (products seized or destroyed, administrative fines);
- Risks related to the socio-economic environment (e.g. health crisis, economic crisis leading to a shut-down of the markets, currency devaluation, strikes, terrorism).
- Risks related to environmental conditions (e.g. water shortages, lack of raw materials, insufficient harvest, prohibitive cost of fruit or vegetables due to climate change, a new harmful invasive species, etc.)

The main risk for small agro-food processing companies usually involves insufficient funding or investment, or a lack of working capital.

In the first case, the project can be jeopardised because there is a lack of supplementary equipment which is deemed less urgent (e.g. refractometer) but which makes the product unsuitable for sale.

In the second case, the project leader invests all of its cash reserves in buying the equipment and the initial lots of raw material and then has no liquidity to continue production because there is always a lag between production and sale which must be factored in!

Another common risk for SMEs is having equipment and facilities which are too small or too big. An inaccurate estimate at the start of the project can lead to equipment being procured which is too big or too small for the requirements, or can cause bad technical choices to be made. It is therefore advisable to consult specialists before making your decision and to use reliable market studies!

1.4.2. The secrets to success

According to the document published by GRET (*Groupe de recherche et d'échanges technologiques*/Research and Technological Exchange Group - a French NGO) and CTA (Technical Centre for Agricultural and Rural Cooperation based in the Netherlands) cited below, there are five aspects which are particularly important to consider.

1. Learning the **composition** of the raw materials and the end product in order to guarantee its quality.
2. Paying **attention to micro-organisms** which may be present during processing to avoid a degeneration of the product and prevent risks of food poisoning.
3. Understanding the **scientific principles which underpin the process** and the factors which can cause an alteration in foods. This will allow you to prevent contamination, degeneration and financial losses.
4. Identifying product **contamination risks** via employees or production methods.
5. Ensuring that the **correct procedures are applied** when handling products to prevent food poisoning.

First and foremost, it is important for future entrepreneurs to fully **understand the physical and chemical composition of the foods** that they produce because this has a bearing on the manufacturing process and the phenomena which can alter and degrade the food, and therefore the level of risk.

Indeed, foods can **contain harmful chemicals or natural substances** which are either **basic components, chemicals from the surrounding environment or substances inadvertently added** during preparation, processing, storage and distribution. These chemicals may come from pesticides used in agriculture or foreign bodies (contaminants) accidentally introduced during processing. Moreover, many foods contain natural substances which are harmful to health (e.g. anti-nutritional factors, mycotoxins, phytotoxins). These must be prevented or removed during processing so that the product can be consumed free from risk.

One of the main objectives of food processing is to **preserve the food**. For this reason, processing must **limit or eliminate the factors which cause alterations or toxicity.** To summarise, these factors are:

- Micro-organisms (some bacteria and viruses can cause food poisoning by contaminating products, especially those with low acidity levels. The acidity level of a food determines the type of micro-organism which can develop in it);
- Enzymes contained in food or released by micro-organisms;
- Environmental factors: temperature, humidity, air, light and acidity of foods can influence the speed of alteration;
- The components of the food itself (water content, acids or natural enzymes).

In addition, during processing it is important to **avoid any physical damage** which may be caused by poor handling as well as any contamination by the environment, the equipment used or the persons handling the food.

The stages involved in **processing** and preserving foods are **very varied, often combined** and are mainly based on:

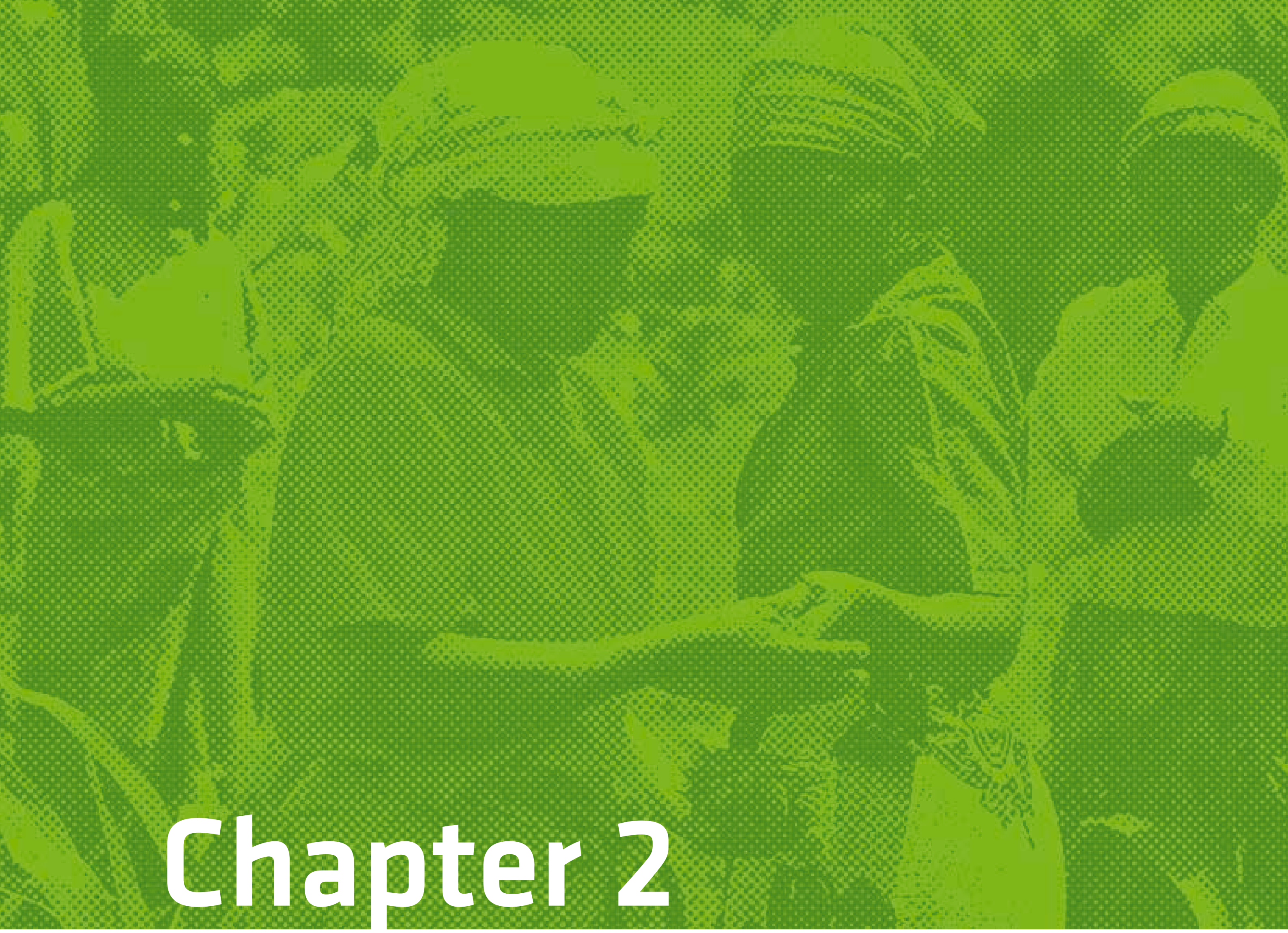
- Removing the water available (e.g. drying) or binding it (with salt or sugar) in order to prevent micro-organisms or enzymes from using it;
- Cooking (pasteurisation, sterilisation): heat is undoubtedly the most commonly used treatment in food processing because it not only preserves the food by deactivating enzymes and micro-organisms but also reduces the level of humidity, modifies the texture, improves digestibility, etc.
- Cooling (refrigeration, freezing or quick freezing);
- Acidity control;
- Adding natural substances (salt, sugar, lemon juice, etc.) or chemicals (preservatives such as sodium or potassium benzoate, sodium metabisulfite, sodium nitrite, sodium nitrate, sodium or potassium sorbate) to prevent micro-organisms from spreading or enzymes from activating;
- Watertight and airtight packaging to insulate the food from its environment, prevent the contents f om leaking and ensure the quality of the food until consumption;
- Controlling the amount of oxygen in the air surrounding the food (modified atmosphere packaging, either by replacing the air in the packaging with carbon dioxide or by extracting it using a vacuum packing machine).

Consequently, all of these aspects are included in this manual, in particular in each chapter which sets out the most common food processing methods.

1.4.3. Further reading

Those interested in gaining further insight on the subject should read the document published under the editorship of P.J. Fellows & B. Axtell, *Créer et gérer une petite entreprise agroalimentaire*, from the "Réussir dans l'agro-alimentaire" collection, ed. CTA & Gret, 2005, 280 p.

According to GRET's website, for those looking to create their own business, the food processing sector offers some attractive opportunities for generating income using locally available resources. However, the road to success is strewn with pitfalls. Entrepreneurs need to have the necessary technical expertise as well as skills in management, marketing and public relations, and an excellent grasp of customer relationships. This manual sets out how to develop or perfect these skills. It aims to help those starting out in the sector avoid the most common errors and improve specific aspects of their business. The subjects addressed include contracts with suppliers and retailers, legal requirements, financial planning and management, record keeping and data archiving, and business management. Each of the ten chapters sets out the secrets to success, a summary of the chapter and a checklist for the entrepreneur. This manual is the result of a collaboration between practitioners supporting small companies in the food processing sector in developing countries.



Chapter 2

The importance of physiology, microbiology and hygiene to preserve and processes products

2.1. THE CONSEQUENCE OF FOOD SPOILAGE

According to the Food and Agriculture Organisation (FAO)[10], "the importance of fruits and vegetables in nutrition, health and the economy is widely known. They are the food most full of vitamins, essential minerals, dietary fibre, phenolic antioxidants, glucosinolates and other bioactive substances. Additionally, they also provide large amounts of carbohydrates, proteins and calories. They have an effect on nutrition and health, making people feel better and reducing the risk of catching certain diseases. Fruits and vegetables therefore play an important role in our daily diet. The current advice is to consume 5 servings per day." However, if these foods spoil after being harvested they lose a lot of their nutritional value and so their goodness.

Food spoilage or rotting is understood to mean **any change that causes the food to lose the desired quality therefore making it unfit for consumption.**

However, " **fruits and vegetables are extremely perishable foodstuffs** adds the FAO. Currently, up to 23% of the most perishable items **are lost during their journey along the agri-food chain because they deteriorate through** rotting, drying out, and being damaged by machines during collection, packing and transport. **It is estimated that losses exceed 40-50% in the tropic and subtropic regions** (FAO, 2012). Losses also occur during storage and during preparation, either at home or in the catering industry. As well as this, in many developing countries, only a limited amount of fruits and vegetables end up at local markets or are exported due to lack of equipment and infrastructure."

In order to limit these significant losses, **it is necessary first to understand the reasons and conditions that cause the spoilage** of products post-harvest. Then, various measures can be adopted or techniques implemented, even unsophisticated ones, that minimise losses during the harvesting, handling, storage, packing, and processing of fresh fruits and vegetables. The result will be products that are more suitable for preservation.

Fruits, green vegetables and root vegetables are all plants **that contain 65-95% water** and whose life processes continue post-harvest. Before being harvested, the quality of these products remains relatively stable as long as they do not become diseased or are not eaten by insects or other animals. But it's not possible to delay harvesting indefinitely: eventually, they will need to be picked. The lifespan of these products post-harvest depends on how quickly they use the reserves that they have stored up and the evaporation rate. When nutrient and water reserves are depleted, the product decomposes and perishes. Factors that may accelerate this process can render the product unfit for consumption.

The main factors and causes of losses are detailed below. There are a variety of causes **and they all have an effect on each other.** Those effects are dependant on external conditions like **temperature and relative humidity** (R.H.)

---

10 This part of the text, in addition to other passages, is extracted largely from the FAO manual, Combined preservation technologies for fruits and vegetables, 2004.

2.2. ANALYSIS OF THE VARIOUS FACTORS THAT INFLUENCE THE PRESERVATION AND CONSERVATION OF PRODUCTS[11]

2.2.1. Objectives of the preservation and conservation of products

After harvesting, **the properties of products** (like nutritional quality, state of health, appearance, freshness, absence of marks, unit weight, shine skin colour, etc.) **should be preserved, or even enhanced, until the time of consumption.**

Regulatory and economic requirements mean products need to be preserved during post-harvest operations, *i.e.* during packing, shipping and distribution. This is to limit the growth of organisms that could harm the health of consumers or that could affect the commercial quality of the products. These rules apply to all products and are decisive both for market competition and meeting health requirements.

There is obviously quite a lot of variance depending on the type of fruit or vegetable. The potential or "ability" to be preserved is a combination of two characteristics of each product:

- **the product's natural ability to be preserved**, which corresponds to the plant's lifespan post-harvest;
- how **effective relevant technologies** are in slowing or preventing product spoilage when applied.

2.2.2. Reasons that products deteriorate

Food spoilage, or rotting, is understood to mean any change that causes the food to lose the desired quality therefore making it unfit for consumption.

As soon as fruits and vegetables are separated from their natural source of nutrients, their quality starts to decline. This is a result of a natural process that starts as soon as the product is harvested and the life cycle interrupted. The fruit or vegetable only has a limited period of time in which to be consumed, varying from a few days to weeks, before it starts to deteriorate and rot.

So even in conditions that are "ideal", or seem to be, fruits and vegetables will perish. **Their limited shelf life is unavoidable.**

11 For more details, see the COLEACP manual, *Principes d'hygiène et de management de la sécurité sanitaire et phytosanitaire* ("Hygiene and phytosanitary safety management principles") from which part of this text has been taken.

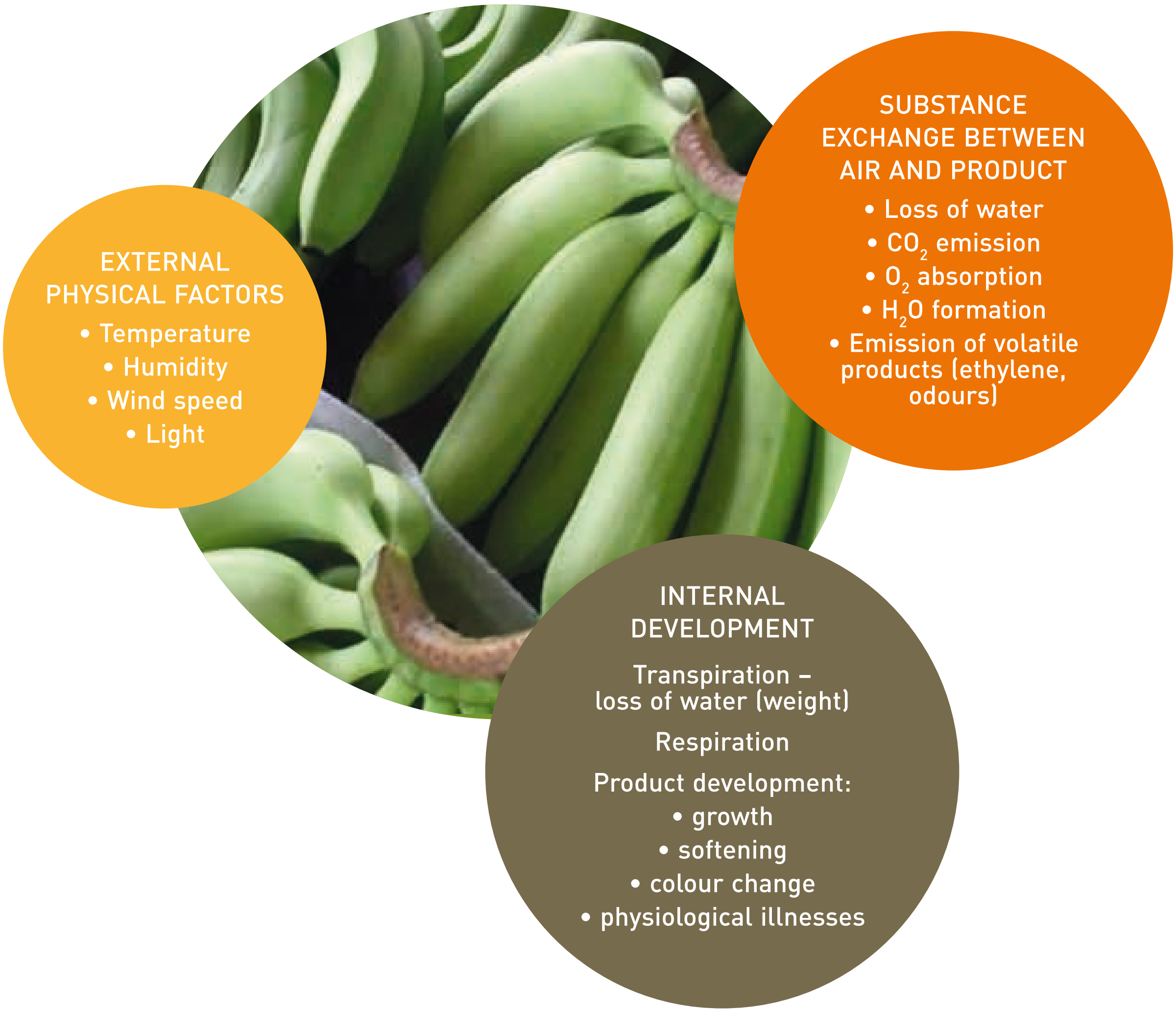
The following table shows the relative risk of loss for some products (source: FAO, A.A. Kader, 1993; a detailed table illustrating the shelf life of various products under ideal conditions can be found in the appendix)

Relative risk of loss	Preservation potential	Products
Very high	Less than 2 weeks	Apricots, cherries, mushrooms, spinach, figs, lettuce, spring onions, ripe tomatoes.
High	2 to 4 weeks	Aubergines, bananas, green beans, mangoes, melons, nectarines, peaches, pears
Average	4 to 8 weeks	Carrots, pomegranates, oranges, grapefruit, raisins
Low	8 to 16 weeks	Garlic, lemon, dried onion, pumpkin
Very low	More than 16 weeks	Fruit grains, dried fruits and vegetables

There are **several types of spoilage:**

1. physical spoilage;
2. chemical and enzymatic deterioration;
3. physiological ageing;
4. spoilage due to insects, rodents and pathogens;
5. damage by machinery;
6. spoilage due to spoilage micro-organisms.

2.2.2.1. Physical, chemical and enzymatic deterioration



The main reason for **physical deterioration** is **dehydration**. Physiological ageing begins as soon as harvesting interrupts the biological cycle. It is actually the case that the physiological functions of the growing plant don't stop when the product is harvested, but they change considerably.

Chemical and enzymatic deterioration occurs most when fruits and vegetables are damaged through falling or being broken, **or as a result of cold.** This releases enzymes that trigger chemical reactions. For example, tomatoes go soft and other types of fruit go brown.

Banana cells have no defence against the cold. When fruit remains at temperatures that are too low, the cells break down and release enzymes that cause the fruit to go brown and soften very quickly (D. Glass, *Moment of science*, 2008)

Lychees evolve very quickly and naturally at room temperature.

In 2 or 3 days, the shell goes brown and then goes dry and crispy. This colour loss happens when the anthocyanin pigments are oxidised.

The fruit is then more likely to burst or be contaminated by fungi.

Currently, sulphur is the only product available that can be used to retain the lychee shell colour, allowing it to last up to 30 days or more (through the export process). The cost of this is not too high. Sulphur prevents the pericarp from going brown as it acts on the shell pigments and prevents enzymatic reactions. However there are a number of drawbacks to sulphurisation of fruit. Residue can be left behind, workers can be exposed to it, etc.

Fruits are also at risk of rotting[12]. Rotting can also be induced by **insects**. They damage fruits and vegetables, which releases enzymes. These processes are inevitable, however they can be delayed by storing agricultural products **in a dry place, sheltered from air currents and at the lowest possible temperature.** They should also be protected from pests before, during and after harvest.

2.2.2.2. Physiological ageing

Three factors come into play during storage if they are not prevented or slowed during processing: **transpiration, respiration** and **tissue metabolism** of the harvested products. The methods of preservation for fresh products (like temperature, atmosphere, and various treatments and types of protection) are intended to influence these factors in order to reach optimal stabilisation.

1) Transpiration

The surface of all parts of a plant are **covered with a waxy skin or a cork bark** that limits water loss. Natural water loss occurs through tiny pores, particularly prevalent on leaves. These pores can open or close depending on the weather conditions. This allows the plant to control the rate of water loss and keep the plants turgid.

Fresh produce continues to lose water post-harvest, but unlike when it was alive it can no longer draw up water from the soil and must therefore use up its internal water reserves. Fresh produce losing water post-harvest is a significant problem as it **causes the product to shrink and lose weight.**

When the harvested product has lost 5-10% of its weight, it starts to wither and soon becomes unusable. In order to prolong the shelf life of the product, water loss must be kept to a minimum.

12 Rotting is caused bythe breakdown of fats leading to an unpleasant change in smell and flavour (and an unpleasant taste when eaten). So dried fruits and nuts (for example cashews) that are rich in fats are particularly affected.

Comparison between green beans that are kept cool (left) and beans exposed to heat during harvest (right).
Note the obvious differences in appearance and colour between the two boxes.
The product on the right is no longer saleable (photo B. Samb).

This **water loss** increases during the storage period and leads to a significantly reduced quality as a result of wilting, softening, deterioration in appearance, etc. It is therefore very important to take this into account.

Percentage water loss resulting in a detrimental change in appearance
(source: Interprofessional technical centre for fruit and vegetables, France)

Leafy vegetables, asparagus	3 to 4%
Fruits, vegetables-fruits	5 to 6%
Root vegetables	7%

Water loss through evaporation depends on two factors.

- Firstly, the morphological characteristics of the organ, in particular the structure of the epidermis and the surface in contact with the air. Water loss can be more or less rapid depending on the product. Leafy green vegetables, especially spinach, lose water quickly because they have thin, waxy skin with many pores. Others vegetables, like potatoes, have a much lower rate of evaporation because of their thick, rough skin with few pores. In terms of water loss, the main thing to note is the connection between the plant surface and its volume. **The larger the surface area compared to the volume, the faster the evaporation will be.**

- Secondly, the **temperature difference** between the air and product as well as the **humidity** and **mix of the** ambient **air**.

  Effect of relative air humidity on water loss: all plants have internal spaces in all of their parts where water and gases can circulate in both directions. The air in these spaces contains water vapour that combines the water from transpiration and that produced by respiration. The water vapour within the plant builds up until the pressure forces it to pass through the pores located on the plant's surfaces. The rate of water loss from parts of a plant depends on the pressure difference between the water vapour inside the plant and the water vapour in the surrounding air outside the plant. **The conclusion is that fresh products need to be stored in a humid atmosphere so as to ensure they lose as little water as possible.**

  The effect of air movement on water loss: the quicker the surrounding air moves over fresh produce, the faster evaporation happens. Air must circulate across the products to remove the heat given off during respiration, **but air movement should be as slow as possible. The conclusion is that better control over air circulation can be gained through well-designed packaging and appropriate stacking of boxes and cartons.**

2) Respiration

Respiration is a cycle of complex biochemical reactions, namely the loss of substrates (sugars and acids) engaged in combustion that then supplies the tissues with energy. Oxygen is absorbed, carbon dioxide is emitted and heat is released. The latter must be removed by refrigeration.

sugars + oxygen = new compounds + carbon dioxide + heat

Products can be preserved for longer if respiration is reduced.

Controlled atmospheres in storage chambers exploit these biochemical phenomena. This original technique was developed to extend the shelf life of some fruits and vegetables.

Effectively, **respiration is reduced by decreasing the oxygen concentration in the ambient air** and also increasing carbon dioxide. Between 0 and 30°C, the rate of respiration increases exponentially. But even at 0°C, vegetables continue to respire.

Respiration level of various products

Very low	Dates, dried fruits, cashews
Low	Citrus fruits, garlic, raisins, kiwis, onions, potatoes, sweet potatoes
Medium	Bananas, cabbages, carrots, lettuces, mangos, tomatoes
High	Avocados, cauliflowers, beans, strawberries
Very high	Brussels sprouts, spring onions, certain types of beans
Extremely high	Asparagus, broccoli, mushrooms, peas, spinach, sweetcorn

3) How metabolism affects a product's development

Metabolism in plant tissues is a series of chemical reactions that characterise a living organ. They are the basis of the changes that can be seen during the life of a plant.

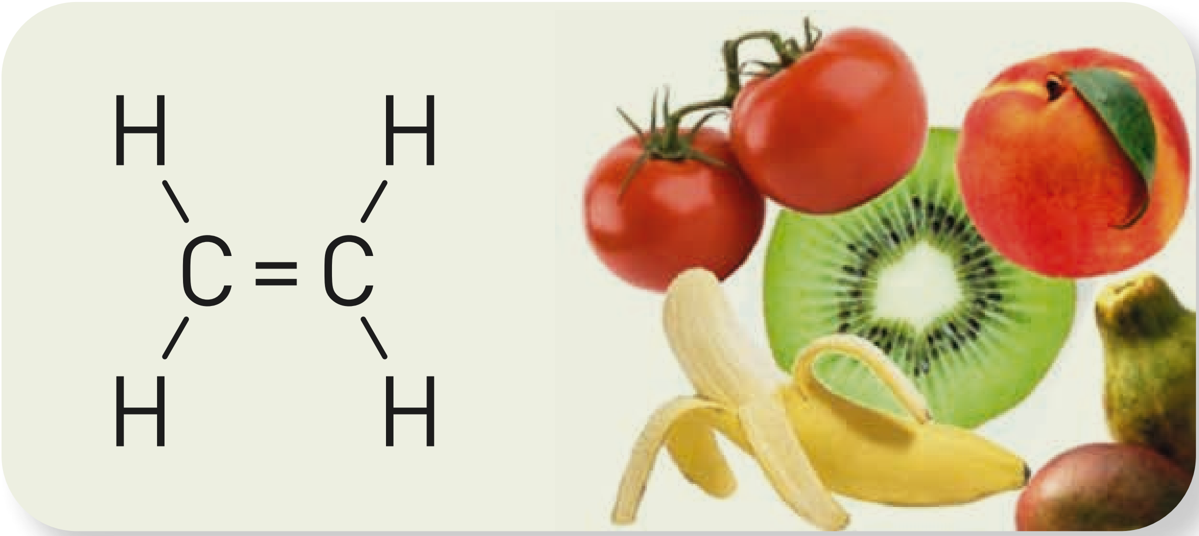
When fruits and vegetables **ripen**, it is the result of a complex set of reactions. These are biological and chemical changes that accelerate development. It leads to a ripened state and gives the product its organoleptic properties.

Ripening improves quality (especially in texture and taste) but it reduces shelf life! The mechanical properties of fruits change dramatically not only as a result of ripening and storage but also during processing. This is due to alterations in their structural components (like the cell wall, middle lamella, plasmodesmata and membranes).

Ripening can be regulated through environmental factors. Temperature, **oxygen, carbon dioxide (CO_2) and ethylene** are all factors that can influence how fruits ripen.

- **Effect of oxygen** (O_2): respiration requires good ventilation. The air contains around 20% of the oxygen that plants require for normal respiration, during which starch and sugars are converted into carbon dioxide and water vapour. If the surrounding air becomes thinner and the amount of free oxygen drops below 2%, **fermentation happens rather than respiration.** Fermentation breaks down sugars into alcohol and carbon dioxide. This alcohol gives the product an unpleasant odour and accelerates ageing.
- **Effect of carbon dioxide** (CO_2): if there is poor ventilation around the product due to thin air, carbon dioxide builds up in the surrounding atmosphere. When the concentration of carbon dioxide in the air around reaches 1–5% (as opposed to normal air content of around 400 ppm, *i.e.* 0.04% of CO_2), the product quickly deteriorates. It releases bad odours, there is tissue dissociation and it stops ripening, among other physiological deteriorations. So, it is evident that products must have good ventilation.

- **The effect of ethylene** (CH_2-CH_2): ripening can be accelerated by the ethylene content in the surrounding air. **This gas is emitted by the fruits and vegetables themselves.** Ethylene affects almost all aspects of plant growth and development. It has an effect on vegetative development (for example, how tall stems grow) and when it comes to plant senescence it can delay or prevent flowering. In pineapples, though, it stimulates flowering, so treatment by products that help release ethylene results in uniform flowering.



Ethylene (CH_2-CH_2) affects almost all aspects of plant growth and development

Products that produce a lot of ethylene (like ripe bananas, apples and cantaloupes) can **stimulate physiological changes in products** that are sensitive to ethylene (like lettuces, cucumbers, carrots, potatoes and sweet potatoes. They can cause unwanted changes in colour, taste and texture.

So care should be taken to check the “compatibility” of products that you want to store together in the same warehouse, for example.

Ripening and spoilage in tomatoes, three weeks after ripening has begun:
ethylene inhibition on the left, no inhibition on the right

A direct proportional relationship has been established between the rate of inhibition of ethylene production and the time needed to delay fruit ripening. To avoid ripening that is too quick, and fruit wilting during storage and/or transport, **ethylene should not be allowed to accumulate in the atmosphere surrounding the products, in storage rooms or containers!**

2.2.2.3. Spoilage due to diseases, insects or rodents

All living organisms are vulnerable to attacks from parasites.

Fresh produce can be infected pre- or post-harvest by airborne, soil-borne or waterborne **diseases**. Some plant pathogens (diseases) can cause spoilage post-harvest. A fruit or vegetable's skin will normally provide natural protection against micro-organisms. Some pathogens can **pass through a product's intact skin**, however **if the skin is damaged by a fall or impact** then the risk of spoilage increases significantly. The most common causes of impacts are careless picking and also stacking fruit or vegetables in piles. Enzymes are produced that break down cell walls, and that leads to decay. As fruits ripen, they become more susceptible to impact and infection that, in turn, causes spoilage. This is partly due to a decrease in antifungal elements and partly due to the breakdown of cell walls. Either way, how badly the product is affected is closely linked to the different post-harvest production stages. Damage caused here is arguably the main cause of loss of fresh produce and has a major impact on how marketable the product is and, therefore, its price.

Insects and rodents ("pests") cause a lot of damage, not only by eating away at the products but also contaminating them with micro-organisms from fur or faeces. Damaged parts of plants are particularly susceptible to bacteria or mould infection.

2.2.2.4. Spoilage as a result of impacts and injury (machine damage)

The high water content and soft texture of fruits, greens and tuberous vegetables mean they are susceptible to machine damage. This can occur at all stages from production to retail, for the following reasons:

- careless picking or harvesting;
- unsuitable containers and boxes – in the field during harvest or when being sold – that have splinters, sharp edges, or are badly nailed or stapled together;
- over- or under-filling containers during harvesting or retail;
- careless handling of products or filled packages, like dropping, throwing or trampling, during grading, transport or retail.

There are several types of lesions that can form:

- fruits, root vegetables and tubers can split when they fall to the ground;
- impacts can cause internal bruise that are not visible on the outside;
- the skin or outer layers of cells of fruits can be damaged by superficial scratches;
- leafy vegetables and other soft products can be crushed.

Lesions that pierce or scratch the skin of a product can:

- act as points of entry for mould and bacteria;
- allow increased water loss;
- increase respiration and, consequently, the release of heat.

Bruises that lie under the intact skin, not showing externally, can:

- increase respiration and the release of heat;
- cause internal discolouration of damaged tissue;
- cause the product to taste odd as a result of abnormal physiological reactions in the damaged area.

2.2.2.5. Spoilage due to micro-organisms

Growing conditions have a big impact on the **microbial flora present** during harvesting. Exposed surfaces can be contaminated through the soil, water, air, by animals insects and also by contact with harvesting equipment.

Pre-harvest fungal infection is usually the main cause of post-harvest rot. For example, Penicillium infects fruits in the orchard and then thrives in warehouses during storage.

Some fungi can penetrate the intact cuticle of leaves, stems and fruits. Other harmful organisms enter the fruit through damage caused by machines during harvesting, handling, packing or through natural openings in the cuticle. They then attack the internal tissues. There are various types of post-harvest spoilage: rot due to brown, blue, pink or grey mould; superficial mould growth; anthracnose (tissue blackening); sour rot; stem end rot; yeast rot; and others.

Harvesting and transport conditions should avoid accelerating product spoilage. Damage by micro-organisms generally occurs due to:

- temperatures and humidity that are too high post-harvest. It is very difficult to balance and maintain the humidity necessary to avoid excessive water loss and the elevated humidity that causes rotting;
- poor harvesting conditions (fruit damaged during harvesting that is picked from the ground or dropped on the ground);
- poor handling and transport conditions (impacts, damage that splits the skin, loose transport);
- poor hygiene conditions during harvesting and transport (dirty crates, unclean transport containers, etc.).

Fruits and vegetables should be handled **hygienically at all times and also very carefully so that no damage is caused that could induce physiological deterioration or allow in pathogens or mould.**

2.2.2.6. Spoilage as a result of cold

All fresh produce can deteriorate if exposed to extreme temperatures (see Appendices). Tolerance to temperature, especially excessive cold, varies greatly depending on the food. If a product is to be put into cold storage then its tolerance to low temperatures is very important. Products freeze at temperatures of 0°C to -2°C. Their subsequent shelf life is shortened because frozen products break down easily.

2.3. IMPORTANCE OF MICRO-ORGANISMS IN THE PRESERVATION AND PROCESSING OF PRODUCTS

2.3.1. Types of micro-organisms that should be taken into account

There are numerous micro-organisms present in and on food products (raw products and end products). Some types are very useful and can even be integral to the preservation process (for example, in lacto-fermentation)[13]. But many are harmful and can disrupt the preservation of food products. Some are dangerous to humans, either in themselves or through their secretions. They are pathogens that affect product **safety**. Others can change the product's properties, like texture, appearance, odour and taste. These affect the **condition** of the product.

There are **three types** of micro-organisms that induce spoilage: **bacteria** (including their spores and toxins), **mould** (including its toxins) and **yeast**. Bacteria and yeast are invisible to the naked eye. However mould forms into filaments or masses that can be seen.

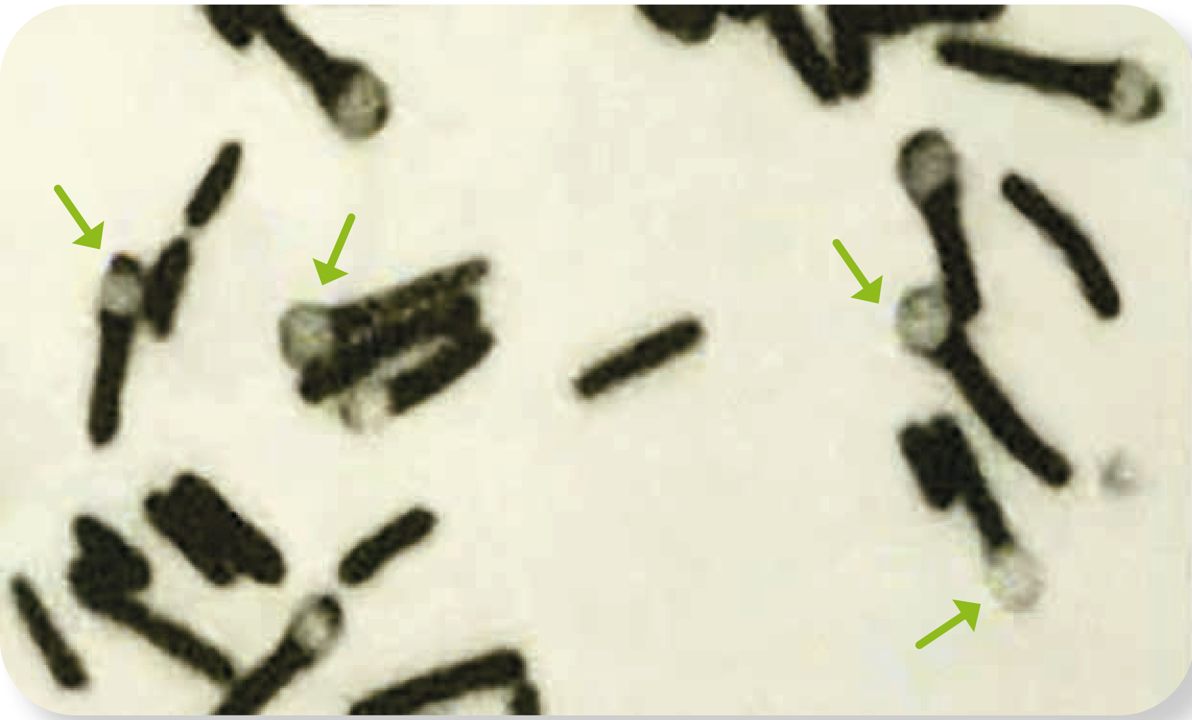
However, it is important to distinguish between the two groups.

2.3.1.1. Pathogenic micro-organisms ("safety")

Bacteria are found **naturally** on and in food products. In low volumes, their impact on consumer health is generally negligible. Nonetheless, there are differences between pathogens such as the speed that they develop inside a consumer and also whether or not a toxic secondary metabolite (toxin released by the bacteria) is present.

Pathogenic bacteria are the greatest biological risk to food.

13 Sometimes, waste excreted by certain micro-organisms can have a positive effect on the food product. For example, lactic acid bacteria are used to make cheese and yoghurt from milk, and make sauerkraut from white cabbage. Tempeh is made from soybeans using certain types of mould, and yeast is used to make beer and bread. This mould changes the taste and structure of food products and generally increases their shelf life. Products keep longer because the micro-organisms that are used lower the pH level, or because their prevalence prevents the growth of other micro-organisms. Using micro-organisms to create food products in this way is called fermentation.



Some pathogenic bacteria (*Bacillus* and *Clostridium)* **produce spores.** Spores are very resistant (e.g. to heat) and can survive for long periods and in unfavourable conditions (cold, dehydration). The **heat-resistance** of spores is due to their dehydration ability (80% water in vegetative form and between 10–20% water as a spore). When conditions become favourable again, for example if a product is thawed, the spores (the bacteria's resistant form) can regain a vegetative form through germination.

Bacteria thrive on almost all types of low-acidity fresh foods like meat, fish, milk and vegetables[14]. They cause the majority of food accidents (foodborne disease outbreaks). Poor food handling and storage conditions can contribute to bacteria proliferation. If not handled and stored properly, cooked foods can often be a Petri dish for unwanted germ growth.

Most of the time it is food products of animal origin, such as raw or undercooked eggs and meat, that are the causes of foodborne disease outbreaks. However, as shown by the **serious health crisis** that hit Germany in 2011, **known as "sprouted seeds", plant products can also be a risk.**

14 Sometimes it is obvious if there is bacteria present (for example, if the meat is slimy, there is gas present, or a putrid odour). But it isn't always so clear if food has spoiled as bacteria doesn't necessarily always cause a change in flavour or appearance. Food that is spoiled should never be consumed in any circumstance as there is a risk of contamination or intoxication (through toxic waste secreted by bacteria).

Escherichia coli O104: H4 bacteria was found on "sprouted seeds" produced on an organic farm in Lower Saxony. It caused bloody diarrhoea, 30 deaths and an unprecedented epidemic with major economic consequences.

Health officials also issued alerts in relation to cucumbers, tomatoes, and lettuces being the prime suspects. However subsequent investigations have shown the possible presence of other bacteria responsible for salmonellosis, listeriosis or shigellosis in these sprouted seeds.

Experts believed that most of the seeds supplied to sprout growers were originally produced for forage crops and therefore had not been subject to good practices. These practices prevent microbial contamination of seeds intended for germination, for example due to the use of natural fertilisers (containing animal faeces) or contaminated irrigation water. Experts think that even if the number of foodborne disease outbreaks (collective food poisoning) involving plants is lower, the consequences in a crisis are always very severe as plant products are often eaten raw.

There are many pathogens or "biological hazards" to take into account when processing and preserving food products. Biological risks can come from contamination of food by organisms (for example, worms) or pathogenic micro-organisms, mainly viruses bacteria, fungi, protozoa, prions, etc. These organisms are often associated with humans and raw products entering the food manufacturing chain.

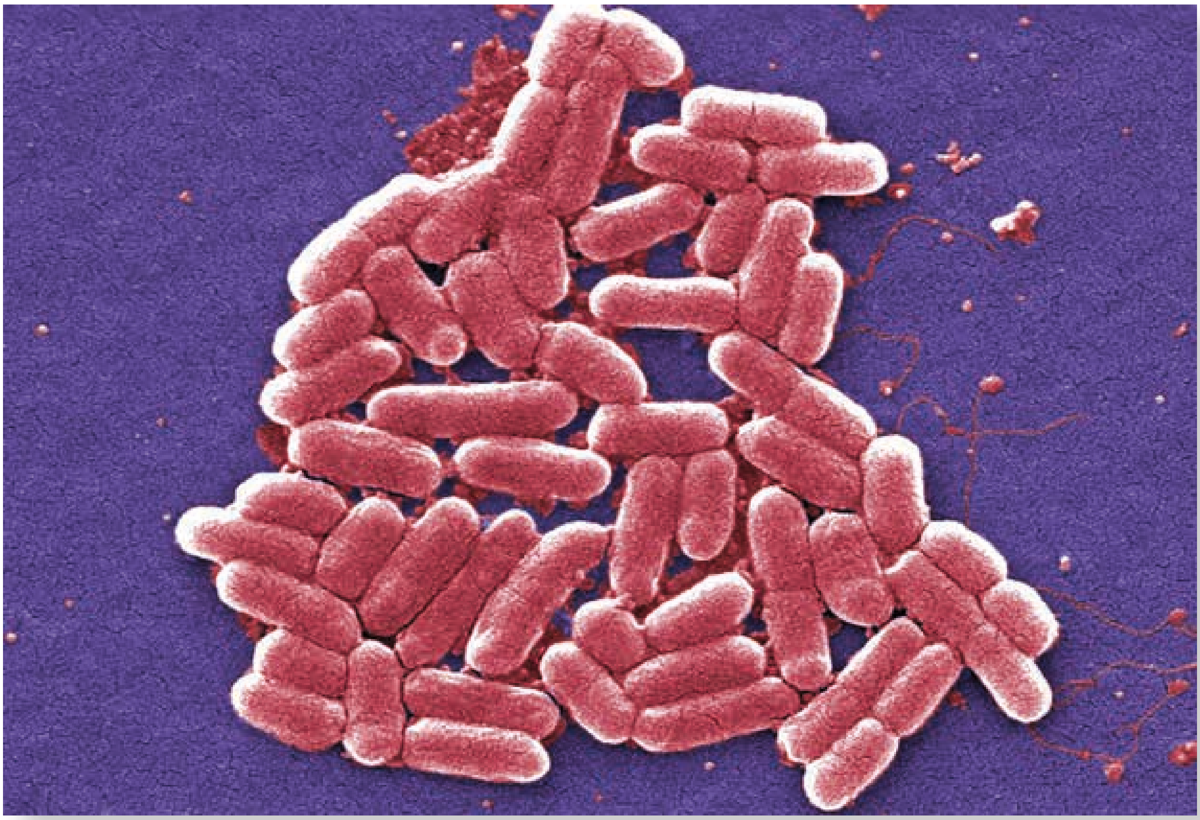
Fortunately, not all of them can infect plant-based food products. But many are part of the natural flora of the environment where food is produced and cultivated.

Examples of biological hazards (Source: FAO Training Manual, 2010)

Spore-forming bacteria	Virus
Clostridium botulinum *Clostridium perfringens* *Bacillus cereus*	Hepatitis A and E, Rotavirus Norwalk virus
Non-spore-forming bacteria	**Protozoa and parasites**
Brucella abortis *Brucella suis* *Campylobacter* spp. Enteropathogenic Escherichia coli (*E. coli* O157:H7, EHEC, EIEC, ETEC, EPEC) *Listeria monocytogenes* *Salmonella spp. (S.typhimurium, S. enteridis)* *Shigella (S. dysenteriae)* *Staphylococcus aureus* *Streptococcus pyogenes* *Vibrio cholerae* *Vibrio parahaemolyticus* *Vibrio vulnificus* *Yersinia enterocolitica*	*Cryptosporidium parvum Diphyllobotrium latum Entamoeba histolytica* *Giardia lamblia* *Ascaris lumbricoides* *Taenia solium* *Taenia saginata* *Trichinella spiralis*

In general, the bacteria present in fruits and vegetables can be divided into three groups.

- **Saprophyte (decomposer)**: enterobacteria (like *Erwinia*…), *Pseudomonas*, *Bacillus* and lactic acid bacteria. When these bacteria develop they reduce the quality of the fruits and vegetables.
- **Phytopathogenic flora** (pectinolytic): some species of *Erwinia*, *Pseudomonas* and *Clostridium*, and others, cause spotted leaves (plant diseases). This flora causes the taste, appearance, etc. of fruits and vegetables to change or degrade.
- **Flora originating from animals** (coliform, enterococcus) and from the earth (soil, water, sewage treatment plants). Enterobacteria are very common contaminants, often acting as indicators of contamination levels and/or pathogens in food and water. They are useful indicators of hygiene and product contamination, for example from unclean hands. "Coliforms", which are enterobacteria, act as indicators in food and are good markers of hygiene levels applied by companies during the handling of foods. **But this flora also produce germs that are pathogenic and that cause food poisoning** if they grow beyond acceptable contamination levels (critical limits). These bacteria can produce toxins that are thermostable (heat stable) and/or thermolabile (readily destroyed by heat).



Escherichia coli

Escherichia coli is a coliform often found in faecal contamination of food. *Escherichia coli* 0157:H7 is a particular serotype that causes numerous illnesses, including haemorrhagic colitis.

2.3.1.2. Spoilage flora (product condition)

Strictly speaking, these micro-organisms don't represent a danger to humans but they affect food product preservation negatively. This then has an impact on the commercial quality of the food. These microbes can affect the taste, smell, texture and general appearance of a product. This **spoilage flora** is principally made up of mould and yeast present on fruits and vegetables.

- **Mould** is often very visible. Mould is a type of microscopic fungi and there are thousand of different varieties. It has a filamentous consistency. Mould is often green but can also be black or brown spots. These micro-organisms can grow and multiply rapidly. They thrive best in damp conditions and in poorly ventilated rooms, at low temperatures and in an acidic environment. Mould evidently changes the taste of products and some types (for example *Alternaria*, *Aspergillus*, *Fusarium*) produce toxic substances (mycotoxins), especially in moist products like seeds or vegetables. Mould that is toxigenic poses a risk to product safety.

- **Yeast** is one of the micro-organisms most commonly found on fresh fruits and vegetables. It prefers low temperatures and acidic products. It can also cause food to spoil, but **is not a source of food poisoning.** Yeast is a common cause of food spoilage, especially in acidic foods like fruits and juices and foods with low water activity (aw). Incidentally, some types of yeast is now used to protect fruit (e.g. apples) in storage. They replace the fungicides traditionally used to prevent the development of *Penicillium*.

The following are acceptable limits that can be applied to food in the ready-to-eat market:

Mould	10^4/g
Yeast	10^4/g

Some mould produces toxic substances (mycotoxins), especially in moist seeds like peanuts, corn and soybeans, or in vegetables

2.3.2. Conditions in which micro-organisms cause spoilage

Micro-organisms develop under certain conditions. They cannot survive without the following:

1. **Sufficient water.** Water is essential for maintaining many physical processes. Micro-organisms can't thrive if water is limited or non-existent (such as in dried vegetables). This is why drying is one of the methods used to prevent food spoilage.
2. **The right temperature (hot or cold).** Micro-organisms can develop in an air temperature of 5°C–65°C. Note that under conditions similar to that of ambient air, the number of bacteria in food can double every 15–20 mins.
3. **Oxygen:** most micro-organisms need oxygen. Without it, they struggle to survive at all, let alone multiply. However, there are always a small number that do survive and as soon as the oxygen increases they start to grow and multiply again. Certain types of micro-organisms, known as "anaerobes", can thrive in low-oxygen, or even zero-oxygen, conditions. One example is the *Clostridium* genus.
4. **The correct level of acidity** as indicated by pH (the more acidic a product, the lower its pH). Yeast and mould can develop more in damaged fruits as they are a bit more acidic. Carrots have a pH of 5 and oranges are around 4. Unlike mould, bacteria prefer lower-acidity conditions. Increasing a product's acidity is a way to slow the process of microbial spoilage.
5. **Nutrients** (e.g. sugars, proteins, fats, minerals and vitamins): these are vital to micro-organisms, but they are plentiful as they are found in all foods.

Evidently, there is a **link between a product's characteristics and how it might become contaminated by micro-organisms.** In order to preserve food, it is sometimes necessary to drastically change the conditions in which micro-organisms are living. The following techniques in particular can be used.

- Remove water(drying), because micro-organisms can't thrive in low-water or completely dry conditions (such as in dried fruits and vegetables). In the case of meat and fish, it's not necessary to dry them completely. **Adding salt** will make the remaining water uninhabitable for micro-organisms. **Adding sugar to fruit has the same effect.** Drying also slows enzymatic deterioration.
- Change temperature conditions (cooling or heating).
- Increase acidity.
- Heating products to kill bacteria and then storing them in airtight containers to prevent oxygen from entering (tins).
- Alter the atmosphere (reduce oxygen, for example in packaging).

2.3.3. The influence of water on micro-organism development

2.3.3.1. The importance of water in fruits and vegetables

Fruit and, to a lesser extent, vegetables generally have high water content (some being up to 85% or even 90% water). Mould thrives in these high water levels. Spores can actually germinate as a result of relative humidity in the ambient air caused by water evaporating from the stored products. Then the mycelium (the vegetative part of a fungus) needs to find "available water" to continue growing.

Water can be **more or less available** depending on the product. Food can either have free water or bound water.

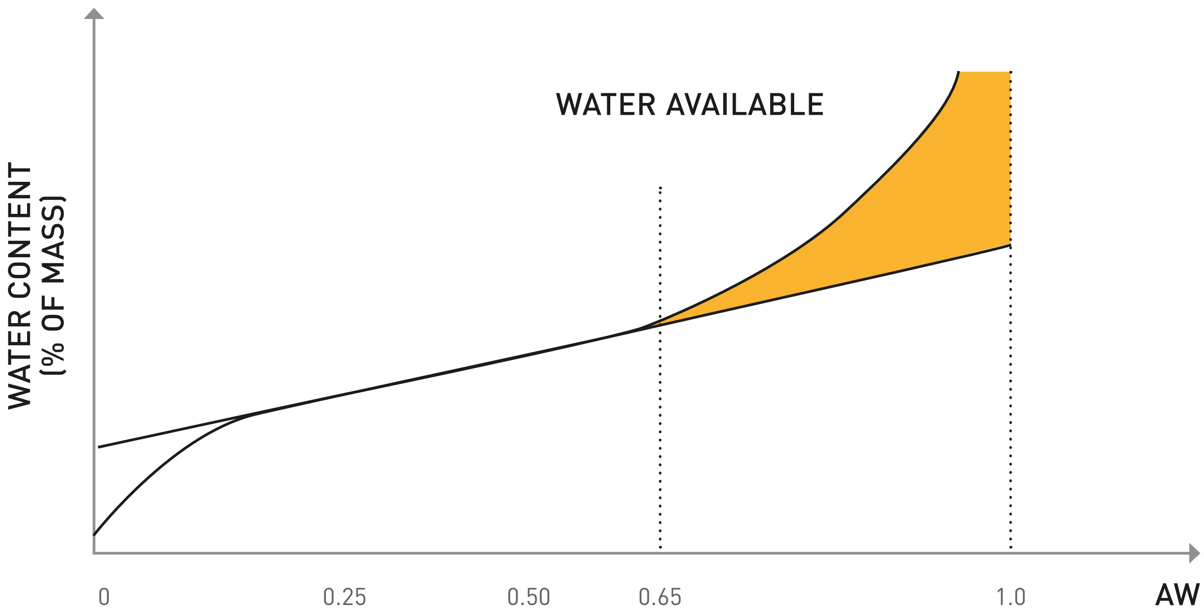
In addition, the different types of water determine how the product is dried.

- **Free water:** free water is found inside a product but it is not bound to the fruit/vegetable components (such as sugars, proteins and vitamins). This type of water behaves like pure water and so **it evaporates easily.** This water type makes a product very perishable as it can be **contaminated by micro-organisms** easily and because it promotes the biochemical and physiochemical reactions that bring about physiological ageing.
- Bound water: unlike free water, bound water is relatively fixed to a product's components by adsorption. It therefore **does not evaporate so easily.** It is also **less easily contaminated by micro-organisms** and is less susceptible to biochemical and physiochemical deterioration.

2.3.3.2. Water activity (aw)

So, the **availability of water** varies depending on the percentage water content of fruits and vegetables as well as their biochemical composition. Water availability is quantified by "water activity" (aw).

An example of a sorption curve for a given product



The "available water" is measured by finding the sorption curve for a given product. This is the relationship between water activity (aw) and the water content of the product. The sorption isotherm displays, at equilibrium at a given temperature, the moisture content of a food product relative to its Aw or the relative humidity of the air in equilibrium with the food. These curves are obtained by placing a food sample in a series of hermetically sealed containers (dessicators) in which a constant relative humidity range is maintained. Then the water content of each food sample is determined at equilibrium. **With sorption isotherms, it is possible to predict and understand how a food product will behave during storage.** The primary information provided by the sorption isotherm is the **hygroscopicity of food.** Hygroscopicity measures the effect that a change in ambient relative humidity will have on a product's water content, if that product is not protected by sealed packaging.

Most of the water in **highly hydrated foods like fruits and most fresh vegetables** is free water (on the surface of the product or in pockets). The rest is poorly absorbed and is retained in the tissue of the product by capillaries.

However, **in processed products** (for example cured meats and jams), the presence of salt or sugar reduced the aw value.

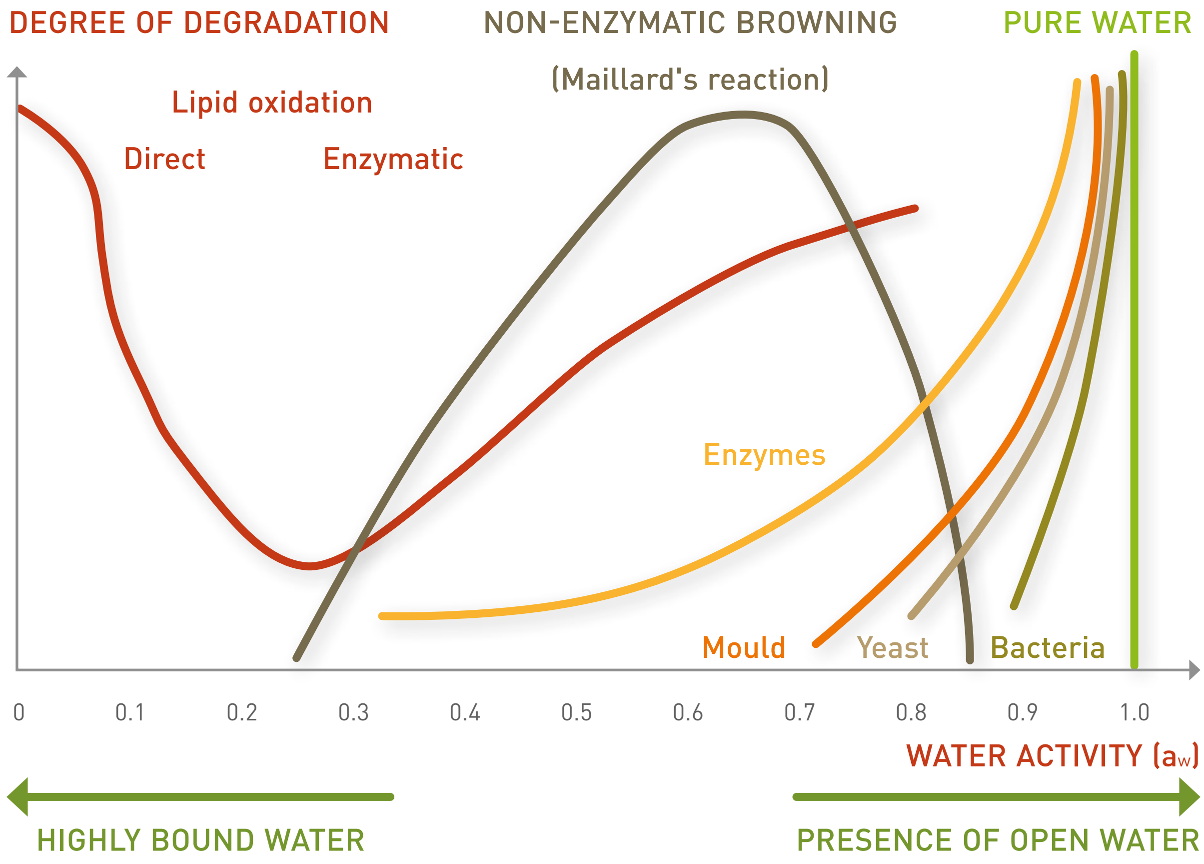
Water activity is defined according to the reference state of pure water, **for which the water activity is equal to 1.** It corresponds to the ratio between the water vapour pressure of the food and the vapour pressure of pure water at the same temperature. The **aw value varies from 0** (a product that is dry to the extent that all the water is bound and therefore there is no reagent quality) **to 1** (all free water).

Aw < 0.25	Strongly bound water ("water of constitution"). This water is not available as a solvent or reagent. It is a layer of water molecules that surrounds the dry matter.
0.25 < aw < 0.65	Water that is weakly bound, but not very available.
Aw > 0.65	"Free" or "liquid" water. It is only weakly retained on the surface of the dry substrate and is available as both a solvent and reagent. Only in this form can water be utilised by micro-organisms and can enable enzymatic reactions.

It has been noted that the fungi that contaminates foodstuffs and that can produce mycotoxins vary in behaviour depending on the availability of water. Some (e.g. *Aspergillus restrictus*) favour very humid environments. Others (e.g. *Aspergillus flavus. A. nidulans, etc.)* like water but not extreme humidity. Finally, some (e.g. *usarium* spp., *Mucorales*...) prefer only slightly humid, or even dry, environments.

Mould does not grow in an aw value of < 0.60–065!

Every type of food has its own sorption curve, which explains why the **water contents in relation to the aw that should not be exceeded (0.65), in order to ensure good preservation, are different.** For example, the water content for good preservation of dried mango is 14g water per 100g of dried mango.



Risk of food spoilage depending on aw

It is possible to predict which micro-organisms are potential sources of contamination by measuring water activity. **A product can be considered stable from a microbiological perspective if its aw is less than 0.6.**

2.3.4. The influence of temperature on micro-organism development

2.3.4.1. The effect of cold on micro-organisms

Micro-organism growth **slows dramatically between0–5°C** (for example in cold storage). This means food can be stored for a number of days. *Listeria*, the bacteria that causes the serious listeriosis disease, multiplies at temperatures of between 3–8°C. So, prolonged storage of food products is difficult.

A contaminated product will not be improved by refrigeration.

At temperatures below 0°C, microbial development stops completely but the micro-organisms are still alive.

Once temperatures rise above 0°C, they begin growing again.

Cold simply slows or stops germs from multiplying. So, a cold store must:

- be washed and disinfected regularly as a product contaminated by bacteria can also contaminate an entire installation;
- not be over-filled, so there is good air circulation;
- avoid cross-contamination by separating products;
- be checked regularly so that the temperature inside corresponds with product storage instructions;
- allow each product to be stored at its ideal storage temperature.

Care should always be taken to keep fruits and vegetables cool (at the temperatures indicated on the label or the packaging[15]).

2.3.4.2. The influence of heat on the development of micro-organisms

One of the most common and effective methods of preserving fruits and vegetables is to prepare them and place them in airtight containers, which are then heated. Micro-organisms are destroyed by heat, **but not all simultaneously!**

High temperatures kill micro-organisms and neutralise enzymes. Most micro-organisms struggle to survive at temperatures above 65°C. Salmonella, the main cause of food poisoning, are only killed when exposed to a temperature of 65°C for 15 minutes or 80°C for 10 minutes. Any remaining spores won't be able to develop into bacteria and the food will be protected from any external microbial contamination. However, it should be noted that some micro-organisms are unfortunately more resistant to heat. For example, *Clostridium* and *Staphylococcus* can still multiply and damage food by producing toxins. *Clostridium* causes botulism and can lead to tragic deaths. This bacteria has difficulty growing in acidic products such as fruit (pH <4.5).

It is difficult to make food 100% safe, but increasing heating time and temperature greatly helps. **Pasteurisation** and **sterilisation** are two distinct methods of eliminating infectious organisms using heat.

15 Remember, never refreeze food or consume food that has been refrozen, even vegetables (refreezing is achieved at -18°C).

- Micro-organisms **die at boiling temperature,** as long as that temperature is maintained for long enough (around 10 minutes). A temperature below 100°C has to be maintained longer to significantly reduce the number of micro-organisms present (such as happens in the **pasteurisation** process).
- Some bacteria (*Bacillus* and *Clostridium genera)* carry a kind of "seed" **called a spore that can survive temperatures of 100°C - even after the bacteria has died.** As soon as the temperature drops, new bacteria develop from the spores. **Spores must be exposed to temperatures of at least 121°C in order to kill them. This is sterilisation.**

2.3.5. The influence of oxygen and carbon dioxide concentrations on the development micro-organisms

Mould is an aerobic organism, so it needs oxygen to develop. However, some types can tolerate low oxygen concentrations and/or high carbon dioxide concentrations to a greater or lesser degree. So, combining these two factors that can limit O_2 gas content and increase the concentration of CO_2 can have a limiting and selective effect on mycotoxin development.

As well as this, there are a minority of species that can tolerate a total absence of oxygen. One is *Byssochlamys nivea* whose ascospores are relatively resistant to the thermal impact of pasteurisation (which increases risks when it comes to preserving fruit juices). Another is the Clostridium genus of bacteria that carries a risk of causing botulism if there is contamination by *C. botulinum.*

2.3.6. The influence of substrates on micro-organism development

Generally speaking, the type of product being stored doesn't significantly influence the micro-organisms' ability to contaminate the substrate(because they find everything that they need).

But there may be some parasite species that prefer **certain fruits and vegetables specifically, such as**: *Penicillium expansum* on apples (and other pome fruit), *Penicillium digitatum* on lemons, *Phytophthora infestans* on potatoes, *Trachysphaera fructigena* on bananas (photo)...

Fruits have natural defence mechanisms such as thick skin and natural antimicrobial substances (essential oils, anthocyanins, benzoic acid, benzaldehyde, etc.) and/ or organic acids (such as malic, tartaric and citric acids) that increase acidity in fruits and vegetables, maintaining a pH of <4.6. However, some fruits, such as bananas, melons, figs and papaya have a high pH. A low pH and the nature of the organic acid itself determines the growth of certain acid-tolerant micro-organisms (mainly mould).

2.4. HOW HYGIENE AND GOOD PRACTICES AFFECT THE PRESERVATION AND QUALITY OF PROCESSED PRODUCTS

2.4.1. The consequences of a lack of hygiene

According to the *Codex Alimentarius*[16], the public has a right to expect the food that they eat to be safe and suitable for consumption. At best, food poisoning and foodborne illnesses are unpleasant. At worst, they can be fatal.

But they can also have other consequences. Outbreaks of food poisoning can **disrupt trade, resulting in a loss of earning, unemployment and lawsuits.**

Food spoilage is wasteful, costly and can negatively impact trade and consumer confidence.

Effective hygiene control is therefore essential to avoid **negative consequences** of food poisoning and foodborne illnesses that could affect **public health and the economy, as well as food spoilage.**

2.4.2. Hygiene and Good Practices: the pillars of health and safety

Our environment – the soil, water and air – is full of micro-organisms that go unnoticed. We ourselves often carry microbes, often without knowing it. The state of our health therefore also influences the safety of some products.

During the technical phase of production, from sowing to harvest, there are many agricultural operations that pose a risk to the products being processed. For example, products used to protect crops or as part of phytosanitary measures before exportation can leave residues that can be toxic if concentrations are too high (MRLs or maximum residue levels). Also, chemicals can bleed from plastic containers, inks or packaging - not to mention food additives that are used to prolong shelf life or for other technical reasons.

To prevent yeast, mould, bacteria, viruses and chemical contaminants from getting into food products in excessive amounts, and thus **damaging both the health and safety of the products**, care must be taken to adhere as strictly as possible to the following principles.

16 Recommended International Code of Practice – Principes généraux d'hygiène alimentaire ("General Principles of Food Hygiene), CAC/RCP 1-1969, Ver. 4-2003.

1. **Basic hygiene rules** that prevent contamination. Like European regulations, the *Codex Alimentarius* define food hygiene as "measures and conditions required to control hazards and ensure the suitability of a food for human consumption, taking into account its intended use".

   This implies that the producer must control **all hazards, wherever they might come from**. This includes hazards linked to micro-organisms as well as chemical hazards (mycotoxins, pesticide residues, heavy metals, allergens, etc.) and physical hazards (pieces of glass, stones, debris, etc.)

   Any of these hazards and threats can arise at any time. They can happen just as easily with the suppliers as with the business itself. They can occur without warning. And they can have consequences, some light but some more serious.

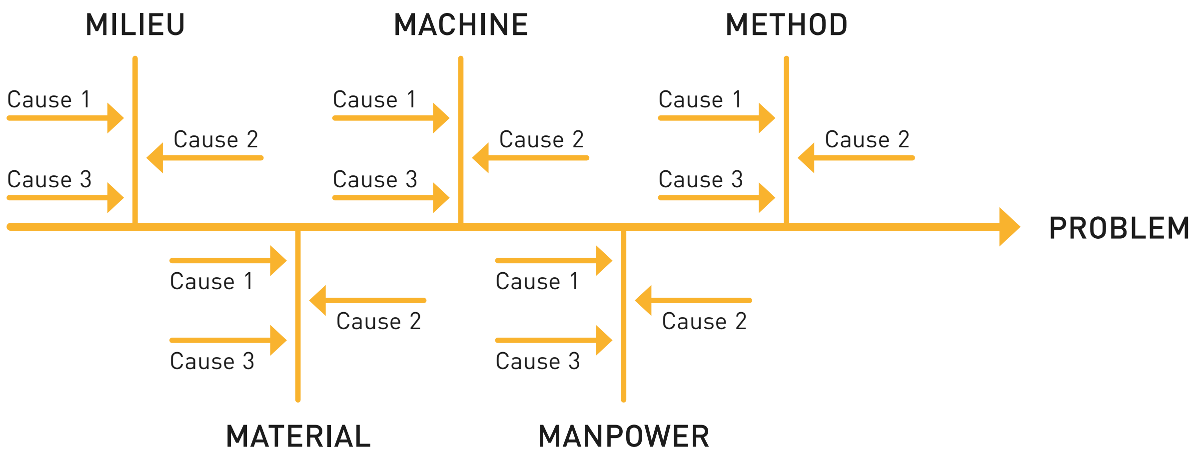
   - For manufacturers, the consequences can be a rapid spoilage of products (due to mould or rot), bans on selling or exporting, negative commercial impacts (damaged brand image, loss of customer confidence, high costs to resolve the crisis, etc.)
   - For consumers, the consequences are adverse effects on health (in extreme cases, death).

2. **Good Practices** when harvesting and preparing fruits and vegetables include avoiding impacts, injuries, etc. These could cause micro-organisms to develop and spoil the product. Also, contact with problematic substances that leave unwanted chemical residues should be avoided.

   "Good practices" are the implementation of measures to control hazards and therefore guarantee that the food products on the market are safe for consumers.

There are a number of varied sources of microbial contamination. The most prominent are those of **natural origin** (in soil, water and air particles, or parasites on insects, rodents, or even birds that get into warehouses) or of **human origin** (food products are also contaminated by people who come into contact with them during harvesting, sorting, cutting, packaging, etc.).

It isn't easy to determine all the sources of contamination within a company without carrying out **a systematic analysis** of company practices. We normally recommend using the "5 M" method, based on the Ishikawa diagram. The Ishikawa diagram (which can be applied to all fields, not just hygiene) is also called the "cause and effect" diagram or the "fishbone" diagram. It is a problem solving tool that looks like this:



This systematic analysis should clarify the tool:

- the causes or consequences of micro-organisms or pathogens that develop on/in food and cause spoilage;
- the causes or consequences of certain chemicals in food;
- the consequences of certain objects being present in the products;
- the consequences of certain allergens being present in the products;

2.4.3. What tools should be put in place?

There are a number of methods that, when combined, provide satisfactory hygiene and safety of processed foods.

- Using a proven technical production method.
- Using a Good Hygiene Practices (GHP) guide. The *Codex Alimentarius* (CAC/RCP 1-1969, Ver. 4-2003) general principles of food hygiene provide a good basis for ensuring food hygiene and should be used in conjunction with each specific code of hygiene practice, as well as guidelines for microbiological criteria. They apply to the food production chain from initial production to final consumption. Hygiene monitoring should therefore be carried out at every stage.
- Training in hygiene, food safety and pest control for staff.
- Establishing a sanitary quality and traceability management system based on a HACCP approach.
- Implementing integrated phytosanitary measures.
- Establishing food safety and pest-elimination measures (verifications, self-monitoring and official monitoring measures).

All these points will be further discussed in Chapter 3.

2.5. APPENDICES

A.1. Damage due to the cold

Some fresh produce can be damaged at low temperatures that are not freezing temperatures. These are mainly products of tropical and subtropical origin, but some temperate crops can be affected.

Effect of refrigeration damage	Symptoms
Change in colour	Internal or external or both, usually brown or black
Holes in the skin	Dents, especially in dry conditions
Ripening anomalies (fruits)	Ripening is uneven or doesn't happen; unpleasant odours
Increased spoilage	Micro-organism activity

A.2. Sensitivity to cold

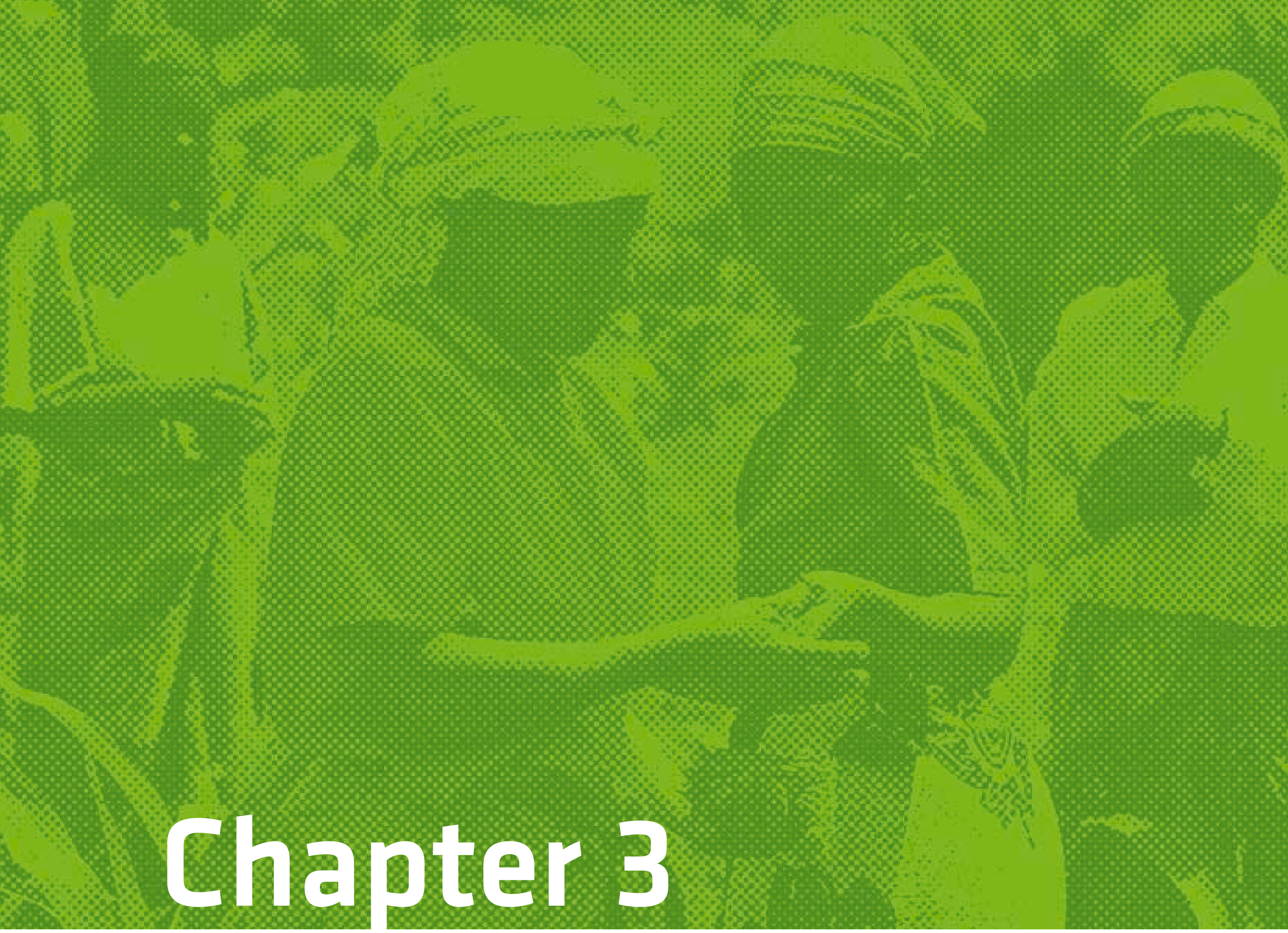
Sensitivity varies depending on the food, but for each product there is a temperature below which it becomes damaged. For same-type foods, the temperature may vary according to variety. Fruits are generally less sensitive to cold when ripe.

Sensitivity of fruits and vegetables to spoilage during refrigeration at temperatures that are low but above 0°C

Food products	Average safe temperatures (°C)	Symptoms
Pineapples	7-10	Dull green appearance, mediocre flavour
Aubergines	7	Scalding on the skin, rotting as a result of *Alternaria*
Avocados	5-13	Flesh turning grey
Bananas (green/ripened)	12-14	Dull grey-brown skin colour
Lemons	13-15	Holes, stained membranes, red patches
Cucumbers	7	Holes in skin, stains filled with water, rotting
Courgettes	10	Deterioration
Okra	7	Loss of colour, waterlogged areas, holes
Green beans	7	Holes, freckles
Limes	7-10	Holes
Mangoes	10-13	Grey scalding on skin, irregular ripening
Melons	7-10	Holes, no ripening, rotting
Oranges	7	Holes, brown stains, watery appearance

Grapefruit	10	Brown scalding, holes, watery appearance
Papayas	7	Holes, no ripening, bad odours, rotting
Watermelons	5	Holes, bitter taste
Sweet potatoes	13	Internal discolouration, pitting, rotting
Peppers	7	Holes, rotting as a result of *Alternaria*
Potatoes	4	Internal discolouration, bland taste
Tomatoes		
• ripened and green	13	Aqueous softening, rotting
• ripened	7-10	Dull colour, abnormal ripening, rotting as a result of *Alternaria*

Source: J.M Lutz and R.E. Hardenburg, "The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks", *Agricultural Handbook* no. 66, 1966, Washington, USDA.



Chapter 3

Pre and post-harvest operations: Hygiene Standards and Good Practices

3.1. INTRODUCTION

During the production and processing of food, contamination is often likely to occur, for example, by bacteria, viruses or other organisms or substances. The sources of contamination in the food industry are many and varied. Despite a desire to do the right thing, producer themselves can be a source of contamination if their hygiene standards are not impeccable, their infrastructure does not lend itself to food processing or they have not controlled their processes perfectly. Yet contamination from food which hasn't been washed, prepared or stored properly, can present a serious risk to the health of a consumer.

Artisan food plays a major role in the promotion and provision of local agricultural products in towns. We must be careful to not oversimplify the issue by demonising the industrial sector in favour of small-scale businesses, when in fact they complement each other and both help supply the market. Artisanal production continues to dominate the market for some products in certain countries. For national markets, activities and products are divided between the two sectors. The industrial sector provides standardised products which are not culturally significant and do not require local expertise, whereas the artisan sector offers traditional products which are highly culturally valued, requiring a lot of specialised knowledge. For a product to be considered artisan, it must have at least one of the following attributes: The main ingredients used or the characteristics of the final product must be unique or high quality, (e.g. taste distinctive); the production and processing methods are mainly manual, giving the product an authentic character; and above all, artisanal production implies **small or very small-scale production**.

With regards to **health risks**, there is a fundamental difference between what is considered acceptable on a so-called artisan (or informal) level, and the consequences of bad practices for production carried out on an industrial scale with large market distribution. This difference is mainly due to the **potential number of consumers** who are likely to suffer from food poisoning if practices went awry, but also very often because artisan production is aimed at local markets, sold directly to the customer, after a **limited storage period,** which reduces the risk of micro-organisms and/or (myco)toxins growing.

When a producer changes from being an artisanal producer to an industrial one, controlling the quality of the raw ingredients and the processes used becomes more complicated, and the level of risk increases in line with production volume. They will therefore need reference documents, such as Good Practice Guides, to help them operate in compliance the *General Principles of Food Hygiene*, the *Codex Alimentarius*, or even implement an HACCP approach in order to ensure the safety and traceability of their produce.

The first step a company will need to make is to put prerequisite programmes (PRP) in place and adhere as closely as possible to the general principles by setting up the necessary controls and records. According to the *Codex*, "**the importance of these programmes cannot be stressed enough**, as they form the foundation for implementing the HACCP plan. Adhering to the General Principles of Food Hygiene and Good Practices (Good Agricultural Practices and Good Manufacturing Practices) will simplify implementing HACCP plans, guarantee that they are integrated and ensure the safety of the manufactured products".

3.2. HARVESTING OPERATIONS

3.2.1. The influence of pre-harvest cultivation practices

It is **impossible to improve the quality of fresh produce after harvesting.** Compliance with regulatory requirements as well as the potential final market value of the products depends on when and where the producer decides to sow or plant, and how they perform their farming operations, *i.e.* their production technical itinerary. **The producer's skill and experience are therefore fundamental.**

This is **largely similar for processed products.** Even though processing (e.g. converting into purée, juice, cordial, jam, etc.) means that products which would not have met marketing standards in their fresh state, can be of value, it is nevertheless difficult to make high quality products from poor quality fresh raw ingredients. Processing fresh products which do not meet regulatory requirements is unimaginable and even forbidden. Making fruit juice or jam from products which may contain residue exceeding maximum residue levels (MRLs)[17] or the maximum limit in the case of heavy metals, **is therefore not permitted.** Diluting, *i.e.* mixing compliant and non-compliant lots to artificially reduce the average level of contaminants, is no longer permitted, even though producers may be tempted to do so. Lot traceability should make it possible to check whether such mixtures have gone missing.

The FAO handbook[18] cites several examples of cultural practices or operations which directly affect the quality of fresh products being used as raw ingredients, some of which are listed below.

- The effect of water (irrigation):
  - excess water or irrigation may cause vegetables to become brittle or fragile;
  - a lack of water may reduce the juice content and cause the skin of citrus fruits to thicken;
  - drought, followed by rain or irrigation may cause potatoes or tomatoes to crack.
- The effect of fertiliser:
  - a lack of nitrogen may cause stunted growth or reddish/yellow discolouration in the leaves of green vegetables, such as cabbages;
  - an imbalance of calcium and humidity may cause the floral tips of tomatoes to rot;
  - a boron deficiencymay cause a loss of turgidity in papaya.
- The effect of crop protection (ineffectiveness causing waste; residue problems; growth regulators used to act on fruiting to achieve uniform ripening, etc.).

17 In contrast, care must be taken to ensure that the processing procedure does not artificially increase the residue concentration of pesticides (e.g. by removing water, thereby reducing the original mass). For the majority of processes, the *Processing Factor (PF)* is lower than 1, meaning that processing (washing, peeling, heating) reduces the residue value (for example, if the residue content is 0.5 mg/kg for the fresh product and the PF is 0.25 after processing, the residue content is 0.125 mg/kg). However, when for example, tomatoes are dried or concentrated, the residue value may increase (PF > 1). See the COLEACP handbook entitled *Principles of Hygiene and Food Safety Management.*

18 Training manual, *Prevention of post-harvest food losses: fruits, vegetables and root crops*, Rome, FAO, 1992.

3.2.2. Determining ripeness at the time of harvest

3.2.2.1. Harvest maturity

For the producer, it is vital to be able to assess the maturity of their products in order to determine whether or not they are ready to be harvested. This will depend primarily on the market (whether it is local or international), consumer preferences and the type and duration of transport (boat, plane, road). The word "maturity" can cause confusion as in addition to its botanical connotations, it also refers to the period during which the plant has finished growing (plant growth) and has reached the flowering and seed production stage (physiological maturity).

According to the FAO, the moment that fruit and vegetable producers decide is the right time to harvest is **critical**. Usually, a fresh product, regardless of its type, is ready for harvesting when it reaches peak condition for consumption. This is generally known as "**harvest maturity**". Harvest maturity therefore determines the period during which the product is ready to be harvested, taking into consideration the time taken to deliver it to the market and transport conditions. Due to this delay, **products are often picked before they are fully ripe**.

To determine the harvest maturity, producers measure the time between flowering and harvesting, including climatic conditions (calculate the number of warm days during the growing season). They also use series of criteria and measures (e.g. Brix) which will be discussed.

3.2.2.2. Ripening process

It is during the **ripening process** that the organoleptic quality of the fruit develops (sugars and acids accumulate, the aromas develop and the textures change).

However, the product will only retain its optimum quality for a short time. It is therefore vital to know the life cycle of products and the ripening process inside out. This will enable producers to know and work out using indicative factors, the **peak time** to pick each type of fruit or vegetable.

This is particularly true for fruit, which can be divided into the following **two categories**: **climacteric and non-climacteric.**

What is a "climacteric" and "non-climacteric" fruit or vegetables?

Fruit and vegetables are known as **climacteric** when they need ethylene (which acts are a plant hormone) to ripen, as it increases cell respiration. These products emit a large amount of ethylene at a specific time (known as the ethylene peak) and **continue to ripen after harvesting**. Over time this leads to softening, colour change, and then physiological deterioration due to senescence. **These products will be picked when green or ripe.**

By contrast, for **non-climacteric** fruit, ripening does not depend on ethylene and is not linked to increased respiration **There is little or no ripening after picking**, but ethylene may cause premature physiological deterioration, such as discolouration and rotting. **These products are picked when they are mature. The quality on the shelf must reflect the quality at the time of harvest.**

Ethylene is a colourless gas which acts as a plant hormone and is produced by most fruit in varying quantities. The molecules cause fruit to ripen, even after it has been picked. Manufacturers therefore try to control ethylene production in fruit with the aim of improving its quality and extending its shelf life. It is also possible to ripen climacteric fruit faster by bringing it into contact with other climacteric fruit. However, care should be taken as climacteric fruit cannot ripen non-climacteric fruit, but will encourage it towards a stage of senescence, which may result in **the fruit spoiling**.

Non-exhaustive list of climacteric and non-climacteric fruit

Climacteric fruit (with a respiration peak)	Non-climacteric fruit (with no respiration peak)
Cherimoya ("custard apple"), apricot, avocado, banana, fig, guava, kiwi, mango, melon, nectarine, peach, pear, apple, tomato, passion fruit, papaya, mamey sapote	Pineapple, cherry, lemon, cucumber, strawberry, lychee, mandarin, blueberry, olive, orange, grapefruit, watermelon, grape, dates, rambutan

3.2.2.3. Signs of maturity in fruit

Several criteria are observed or measured to determine harvest maturity.

- **Colour**: this is an essential feature what fruit looks like and therefore, will determine whether the consumer's first impression is positive or negative (this may vary depending on consumer nationality).

  Colour is also used as a quality criterion, allowing food products to be divided into several categories that consumers can easily refer to when making their choice. There are **two categories of pigments**: carotenoids, which accumulate as the fruit ripens and turns from green to red, andanthocyanins, which are responsible for the red colour off strawberries or mangos, for example.

  However, great care must be taken, as there is not necessarily a link between the appearance of a fruit and its physiological age. The colour may change depending on the amount of sunshine received on the tree, its size, etc.

Mango receiving a lot of sun   Mango in the shade   Large   Small

All these mangos are the same level of ripeness
(Source: Gleizer and Joas, CIRAD-CITFL, 2013)

- **Fruit firmness**: this can be determined by tapping the fruit and listening to the sound. This causes a chemical synthesis or activation of proteins involved in softening the wall during the ripening phase. Pectin forms a part of these proteins and is present in the form of chains. The longer the chain, the harder the fruit.

Firmness is a quality criterion which is controlled upon receipt of the fruit.

Measuring fruit firmness is one of the criteria which allows producers to work out the best time to pick. It gives a quantifiable indication of the hardness or softness of a fruit. The most commonly used solution for this type of measurement involves measuring **the force required to drive a calibrated tip** (a small metal cylinder screwed onto the device) **into the flesh of the fruit**, using a dynamometer or a penetrometer. Measurements are generally taken in Newton or kg which are then brought back to the surface of the penetrometer for uniformity. To take the measurement, remove the skin from the fruit is removed, then insert the tip manually into the flesh of the fruit and record the indicated value on the instrument.

We can distinguish between **3 type of firmness depending on the distribution chain**: harvest, transport and consumption. If, for example, an apple is not firm at the time of picking, there is a strong possibility that it will be soft when it reaches the end consumer.

Example of penetrometer which measures fruit firmness.
There are two manual models of penetrometers.
One has a scale from 0 to 5 kgf for soft fruit,
whereas another has a scale from 0 to 13 kgf for hard fruit.

Care must be taken to ensure that the samples measured are representative of the whole crop (regarding the minimum number of sampling units, size, quality, etc.). It is important that the fruit selected is healthy and has no specific problems due to disease or physical damage which could affect the normal ripening process. It is best to take several measurements of the fruit in different directions. The same type of sampling can be carried out to inspect a lot of stored or transported fruit.

The following table shows some firmness indicator values (in kgf) for the 3 different stages: harvest, during transportation and at the time of consumption

Fruit	Diameter of the metal tip used	Harvest	Transportation	Consumption
Apple	11.3 mm	8 kgf	5-6 kgf	4 kgf
Melon	8 mm	4-5 kgf	3-4 kgf	3 kgf
Kiwi	8 mm	7-8 kgf	3-5 kgf	2-3 kgf
Mango	8 mm	8-9 kgf	3-5 kgf	2 kgf
Nectarine	8 mm	6 kgf	5-7 kgf	1-2 kgf
Orange	8 mm		2-3 kgf	
Avocado	6 mm	14-15 kgf	8-10 kgf	

The tips are standardised and have the following diameters as an example:

- 11.3 mm (1 cm^2) for apples (pressure applied: 4.32 kg/cm^2)
- 8 mm (0.50 cm^2) for mangos, oranges, pears (pressure applied: 8.64 kg/cm^2)
- 6 mm (0.28 cm^2) for avocados and kiwis (pressure applied: 15.43 kg/cm^2)

Comments: kgf = kilogram-force, a metric unit which is converted into Newtons by multiplying the value by the acceleration of gravity (which is 9.806 65 m/s^2, *i.e.* 9.806 65 N (N = kg × m × s-2). 1 kgf = 9.806 65 N; 1 N = 0.101 972 kgf). Example: 8 kgf = 78.4 N.

- **Smell**: as fruit ripens, it produces specific volatile compounds. This is what gives a fruit its smell. This is why several types of fruit give off a specific smell when ripe. These aromas are difficult to measure, as they depend on a large number of factors. Nevertheless, they give a good indication that the fruit is ripe.
- **Fruit flavour**: this is generally linked to the concentration of sugar and acid in a fruit, mainly fructose and citric acid. The best combination, *i.e.* **the best flavour comes from those high in sugar and acid**[19]. During ripening, the sugar content will increase as the fruit's starch breaks down. The starch changes into glucose, fructose and sucrose, *i.e.* simple sugars, by hydrolysis. As starch is mainly present in the end of the stem, the fruit should not be picked too early so that it is able to accumulate enough sugar (with the exception of climacteric fruit).

  The sugar content of a fruit can easily be measured using a refractometer. It makes use of the fact that a beam of light is deflected differently depending on the nature of the environment in which it propagates.

  Therefore, depending on the sugar content of the juice, the deflection of daylight by the sample varies and **indicates its Brix value**. When the Brix content is high, the freezing point is much lower and the vegetables or fruit freeze much less quickly.

19 Some products (such as Bristoner®) allow sugars to be transported from production centres (leaves) to the fruit during the development and ripening phase, using the process of photosynthesis.

The Brix scale measures the proportion of sucrose in a liquid, *i.e.* the percentage of soluble dry matterin Brix degrees (°B or °Bx). The Brix degree of fruit pulp can be measured once it has been prepared (sorted, washed, centrifuged, etc.). **To do this, a small amount of juice is taken from the preparation** and is placed on the refractometer. This is how the Brix degree of a fruit is obtained. **The higher the Brix °, the higher the sugar content** (% of sugar in the tested juice in the refractometer. 20 Brix° = 20% sugar. It is generally lower than 20% for fruit; **an average of 13% for most tropical fruit** (19-20% for pineapples; 12-22% for mangos).

Some instruments measure both the Brix and acidity at the same time.
How the sugar and acidity levels develop after harvesting depends on the species.

3.2.3. Managing the risks associated with harvesting operations

The harvester must plan to carry out the following operations within an appropriate timeframe:

- Harvest good quality products in good condition.
- Store the picked produce in good condition until consumed or sold.
- Plan to harvest within appropriate timeframes (provide sufficient labour, equipment and means of transport).
- Provide training for the whole workforce in the general aspects of product handling and more specialised training for those who will be responsible for more challenging tasks.
- Put in place a system for monitoring all stages of the harvesting process and field work.
- Organise operations (picking, local sorting, transport to the processing facility or factory).
- Check the condition of crates for harvesting and the contents (e.g. seals). Avoid dirty containers which have been contaminated by soil, plant residue or decomposing products; contact with oil, petrol or other chemicals other than those which have been specifically authorised for post-harvest processing.
- Anticipate the equipment required to follow personal hygiene rules (water points for hand washing, clean and accessible toilets, etc.).
- Collect and eliminate waste and sorting deviations.

The health measures applicable to anyone working in the food sector also apply to those in the primary sector.

Personal hygiene begins in the field. Washing hands before and during picking reduces the risk of products being contaminated by workers.

3.2.3.1. Risk of mechanical damage (impact, skin damage) by rough handling during harvesting

As fruit and vegetables (fruit, green vegetables and tuberous vegetables) have a high water content and therefore a soft texture (even softer as the time for harvesting as they become riper), they are very sensitive to shock during harvesting operations. Skin damage can occur at all stages, from production to retail sale, due to unclean, mechanical or abrupt picking or harvesting operations (e.g. tree shaking), crates in poor condition (containing splinters or nails, etc.), rough dumping into a bin, accidental trampling, etc. (e.g. sometimes pineapples are thrown into a harvest bin from a height).

Cracks, bruises and wounds are all points of entry for fungi and bacteria which can spread even more rapidly as at that particular moment the products contain a high sugar concentration. The consequences are wide-ranging and include fermentation, colour change to the damaged tissue, pronounced aftertaste, etc.

Harvesting operations should therefore be well-organised and planned so they do not have to be rushed. Instead, most products should be handled carefully and gently to avoid shock and damage. Stalks should be cut using a sharp knife, instead of being torn off.

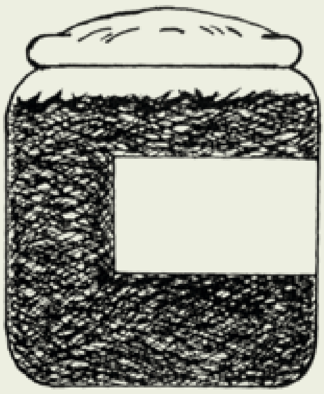
3.2.3.2. The effect of ripeness on harvesting operations

When fruit is ripe, it is a lot more fragile and sensitive to shock, damage and therefore to diseases which develop post-harvest when stored before packing or processing.

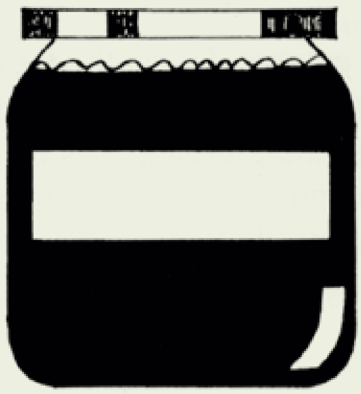
3.3. PREPARING PRODUCTS POST-HARVEST

Fruit and vegetable preparation, whether for processing (e.g. Into juice, purée, jam, conserve, etc.), or for direct packing (packaging of fresh produce to be shipped), must be performed **as soon as possible after harvesting**, and in all cases within 48 hoursfor fresh fruit and vegetables. Any longer and the risk of spoiling (enzymatic deterioration, fungus or pest, mould growth, etc.) increases.

Examples of spoiled products (taken from AGRODOK Series no. 3, CTA, 2003)

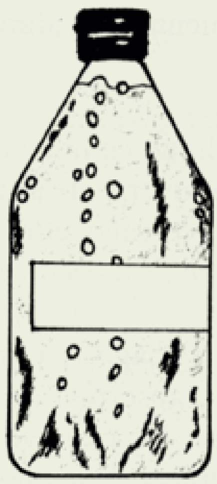


BULGING LID DUE
TO GAS FORMATION



FORMATION OF SLIME
COATING ON PRODUCT

MOULD GROWTH



FORMATION OF GAS BUBBLES

This phase precedes either the packing stage of fruit and vegetables to be sold fresh, or their processing into juice, purée, jam, jelly, ketchup, etc. and includes several essential operations. However, production models are many and varied, and operations do not necessarily take place in the order illustrated below. Some operations are not always performed as a matter of course.

3.3.1. Primary sorting

Primary sorting, which usually takes place in the field, allows producers to remove anything which cannot be sold and foreign bodies (plant, soil or stone debris). This is performed before transportation and before the product enters the packing facility or factory, and moves on to subsequent operations. All waste will be quickly eliminated or kept in closed bins for disposal. The accumulation of decomposing or infested waste, whether in the field, the storage area or nearby, will contaminate other products (e.g. mangos bitten by fruit flies).

3.3.2. Cleaning and washing

[20]**Sorting and cleaning fruit and vegetables while fresh before packing or processing**, is not only permitted, but recommended, in order to remove sand, soil and any remaining dirt.

Soil and stone can be washed off by hand or using a sieve. Some products can be washed, brushed or cleaned using a soft cloth (e.g. mangos). Cleaning products by polishing them by hand or brushing them with a machine allows traces of soil or dirt on the surface of the product to be removed, particularly from fruit. This work should be carried out with care, as fresh produce containing skin which can scratch, will damage easily.

Fruit and vegetables should first be thoroughly cleaned to remove any remaining dirt or external pesticides. The outer skin of onions should also be removed. Cleaning generally consists of washing the products, preferably with running water under **drinking tap water** or, failing that, **in a bucket of clean water that is changed regularly**. At this stage of production, using drinking water is not compulsory, but is advised. However, clean water will suffice. Either way, the producer must obviously ensure that they do not contaminate their products with micro-organisms or chemicals.

There are no acceptable or effective antibacterial agents that can be used to treat water used to wash fresh produce. Hypochlorites or chlorinecan be added to washing waterused for commercial treatment of some products, but their use in recycled or stagnant water cannot be recommended for small washing operations as they will quickly become inactivated by organic matter, such as plant debris, in the water. It is difficult to control the concentration of chlorine in the wash water and its dose. In any case, the effectiveness of chlorine against decomposition is limited.

Products which have sustained bruising during harvesting, resulting in **latex stains,** should be washed: **this is particularly the case with mangos and bananas.** It is worth noting that these products should only be washed if absolutely necessary. In this case, an antifungal agent should be applied as soon as possible afterwards.

When cleaning leafy vegetables, it is best to remove the stems first. Certain types of fruit and vegetable should never be washed, such as cherries, strawberries, mushrooms, salad, green beans, cucumbers, etc. because this encourages micro-organisms to propagate and shortens their shelf life.

---

20 From a regulatory perspective, these operations do not change the destination of the product (to non-use), are not different to "primary production" and do not change the requirements relating to HACCP obligations, for example.

For some products, such as lettuce, instead of washing, some of the outer leaves can be removed (pared). These are the leaves in contact with the soil and are therefore the dirtiest. The are also the ones which are most contaminated with residue (e.g. fungicide) as they are the oldest and were therefore formed during treatment. By removing them you are removing a large part of the residue of phytosanitary products. For pineapples, some of the crown can be cut off.

Washed products which must be treated with fungicides should first be drained in order to reduce the risk of residual wash water diluting the antifungal agent below its effective concentration. If a washed product does not need to undergo antifungal treatment, it will be arranged in a single layer on raised trellises or on slats in the shade, well-ventilated, to allow rapid drying.

3.3.3. Fungicide treatment

Fungicide treatment is carried out on products which are unprocessed, but will be stored and transported long distances. Due to the damage that can be caused by yeast, mould and bacteria during transportation and storage, products are sometimes carried soaked or sprayed with biocides, including fungicides. It is worth noting that only certain fungicides (including Imazalil and Thiabendazole) may be applied in this way post-harvest, as the effective dose at the time of treatment cannot exceed the MRL value for the active substance (it can actually be consumed immediately, during the days following treatment). Today, biopesticides (e.g. yeast) sometimes replace synthetic active substances, especially since, when the active substance is no longer authorised in Europe, the MRL value is reduced to 0.1 mg/kg, making treatment impossible due to excessive residue.

Bananas and citrus fruit (non-organic) are practically always treated with fungicide. However, avocados, mangos, apples and even peppers, are treated just as often with fungicide before storage or marketing.

Bananas left to dry after soaking in a fungicide bath

The commercial product (formulation) is dispersed in water before being sprayed on the moving fruit on a conveyor belt, or dispersed in a large tank (bath) in which the fruit is immersed. There are **two application methods**.

- **Spraying:** this can be carried out using fixed jets (the fruit is on perforated trays and passes through the spray mist or is carried by a belt or roller conveyor). In small facilities, a knapsack sprayer is sometimes used to apply the fungicide to the product, which is placed on trays after washing and drying. Whichever technique is used, the fruit is sprayed to refusal, *i.e.* to the point of running off.
- **Bath immersion:** this method is done by hand. The trellis baskets allow several fruits to be soaked at the same time. After soaking, the product will be drained and dried in a ventilated area out of direct sunlight.

3.3.4. Soda bath

Some products, such as plums or grapes, are immersed for 5 to 15 seconds in a pan containing hot near-boiling soda (NaOH; 10-20g soda per litre of water), which makes the skin rough and speeds up the drying process. After this treatment, the fruit should be thoroughly rinsed with cold water to remove any remnants of soda. Lemon juice also neutralises any soda residue.

The method described above pollutes as the alkali content in the water ends up in the environment. Using soda has additional disadvantages, such as the risk of discolouring vegetables and corroding metal pans. Using too high a concentration of soda is unhealthy for the people who use it.

3.3.5. Peeling and cutting

Many types of fruit and vegetables are peeled in order to be preserved. Peeling can be performed easily using a stainless steel knife. This detail is important as it will avoid discolouring the flesh of products. For citrus fruits, tomatoes and peaches, whose skin adheres tightly to the flesh, it is best to plunge them into hot water for 1.5 to 3 minutes. The softened skin will then come away easily.

It is important to chop products, as roughly equal pieces are needed for cooking, drying and packing. Fruit and vegetables are usually cut into cubes, thin slices, rings or shreds. **The equipment used must be well-sharpened and clean to avoid micro-organisms coming into contact with the food.** From the moment they are chopped, the quality of the product id reduced due to the release of enzymes and nutrients for micro-organisms.

Quality is also reduced by damaging the flesh when chopping. For this reason, the time between peeling, cutting and preserving has to be as short as possible.

Peeling and packing mini-vegetables in Kenya

Given that the product is handled several times, it is essential that personal hygiene and equipment cleanliness are made a priority.

The health risks presented by this type of operation are no longer comparable to those of simply washing products. An HACCP approach is required to identify the appropriate control measures.

Used knives are cleaned and sanitised during work by soaking them in sanitising solution
(Photos B. Schiffers)

3.3.6. Blanching

3.3.6.1. Principles of this technique

Whilst washing can remove surface organisms, some operations, such as peeling, cutting and slicing can damage cells by exposing nutritional fluid from the inner tissue to the external environment and providing a new access site for micro-organisms and other contaminants.

Blanching, or "pre-cooking" is done by **exposing fruit and vegetables to high temperatures (90-95 °C) for a few minutes.** It therefore involves briefly pre-cooking vegetables we would usually consume cooked, to water or steam, in order to preserve them by canning, dehydration or freezing. Blanching can be done using ordinary water or soft water containing 0.2% Na_2CO_3 which does not change the natural colour. For hard vegetables (such as peas), NaCl (3%) is added to make them tender.

3.3.6.2. Advantages of blanching

Blanching has several objectives.

- **It completes the washing stage**, reducing chemical contamination and microbial load.
- **It tenderises vegetables** while keeping the original colour, reducing the volume (leaves, which makes subsequent operations and handling easier).
- **It eliminates air and gas trapped** within the plant tissue, avoiding oxidation during the subsequent heating phase, or acceleration of later corrosion of metal containers.
- **It allows better control of the variable water content** depending on the level of maturity. Most vegetables lose water to some degree during cooking (spinach, peas, etc.). Legumes, on the other hand (such as beans), take on a degree of water during cooking. Blanching helps regulate these gains or losses.
- It is an operation requiring critical control to transform them into stable products. With these traditional preservation methods, treatment using heat has the primary function of **destroying the enzymes** which are likely to spoil fruit and vegetables. If they are not blanched, there remains the risk of enzymatic abnormalities, even after sterilisation. These abnormalities include:
  - loss of natural smell or flavour;
  - an accumulation of decomposition products which give an unpleasant aftertaste and smell;
  - colour change due to enzymatic attack of chlorophyll. The polyphenoloxidases transform natural phenols into reddish-brown pigments under the action of O_2;
  - lignification and hardening of peas.

However, in these minimum processing techniques, blanching serves another important purpose, which is **to reduce the initial microbial load** by deactivating heat-sensitive micro-organisms. The temperatures used are lethal to yeast, most mould and aerobic micro-organisms. Blanching has been found to **reduce microbial load from 60 to 99%.** Furthermore, heat treatment has a sensitising effect on the survivors, making them less resistant to the stresses imposed by the reduction in water activity and pH, as well as the presence of sorbate and sulphites or other anti-microbial agents.

Vegetables are blanched before drying, **in order to prevent them from changing colour or smell**, and to stop them losing too many vitamins. As a general rule, it is not necessary to blanch fruit which does not discolour. Certain vegetables, such as onions and leeks, do not react well to blanching.

3.3.6.3. Disadvantages of blanching

Blanching has some disadvantages:

- excessive softening of some products;
- loss of nutrients (vitamins, mineral salts, sugars) by diffusion in water;
- loss of thermolabile constituents (vitamin C), therefore blanching must be performed at a high temperature for a short time;
- chlorophyll transformation, causing green vegetables to turn yellow;
- destruction or formation of odorous, aromatic compounds.

3.3.6.4. How to blanch

Blanching is fairly simple. You just need a large pan with a lid and a metal colander or one which is heat-resistant. Submerge the fruit and vegetables into very hot water (> 90° C).

The disadvantage with this method is that many vitamins will be destroyed by the boiling water. That's why is it better to blanch products using steam.

How to blanch a product

Put the fruit or vegetable in a colander (a linen cloth with a cord will also do) and add water under the food. Bring to the boil and cook for 2 to 5 minutes maximum. Remove any froth, if necessary. Next, stop the food cooking by refreshing in cold running water and draining. You can also use a drinking water receptacle as long as it is fresh and clean. During blanching, you need to monitor the temperature of the water.

You can also expose the food to steam, which will soften the product and remove the enzymes while keeping the vitamins intact. Leafy vegetables lose mass and **some of their micro-organisms die**.

Two elements need to be monitored:

- **Water hardness**: calcium and magnesium ions in the water have properties that cause them to react with the pectic compounds making up the plant cell walls. In practice they reinforce the structure of the vegetable and strengthen the product. Therefore, vegetables blanched in hard water are firmer and legumes lose less starch in the covering liquid (resulting in a less cloudy juice). Very hard water can cause a product to become too firm. During blanching it is necessary to **control the water hardness** in order to control the firmness of the vegetable. It may be necessary to add calcium salt permitted by regulations in order to maintain optimal texture.
- **Duration and temperature:** the average is 4 minutes and 90 to 95°C. The average values also depend on the variety and degree of maturity. Generally speaking, the riper the product, the longer it takes. Blanching must be performed under very strict conditions and the utensil must be carefully cleaned and sanitised frequently, otherwise it may become a contaminant. The water quality is important.

3.3.6.5. Industrial techniques

Blanching by hot water immersion: spiral blanching machines are the most commonly used. A spiral screw which is partially or fully immersed lowers the product into the hot water. Low-calcium water should be used and should be changed frequently. This technique produces a large amount of residual water.

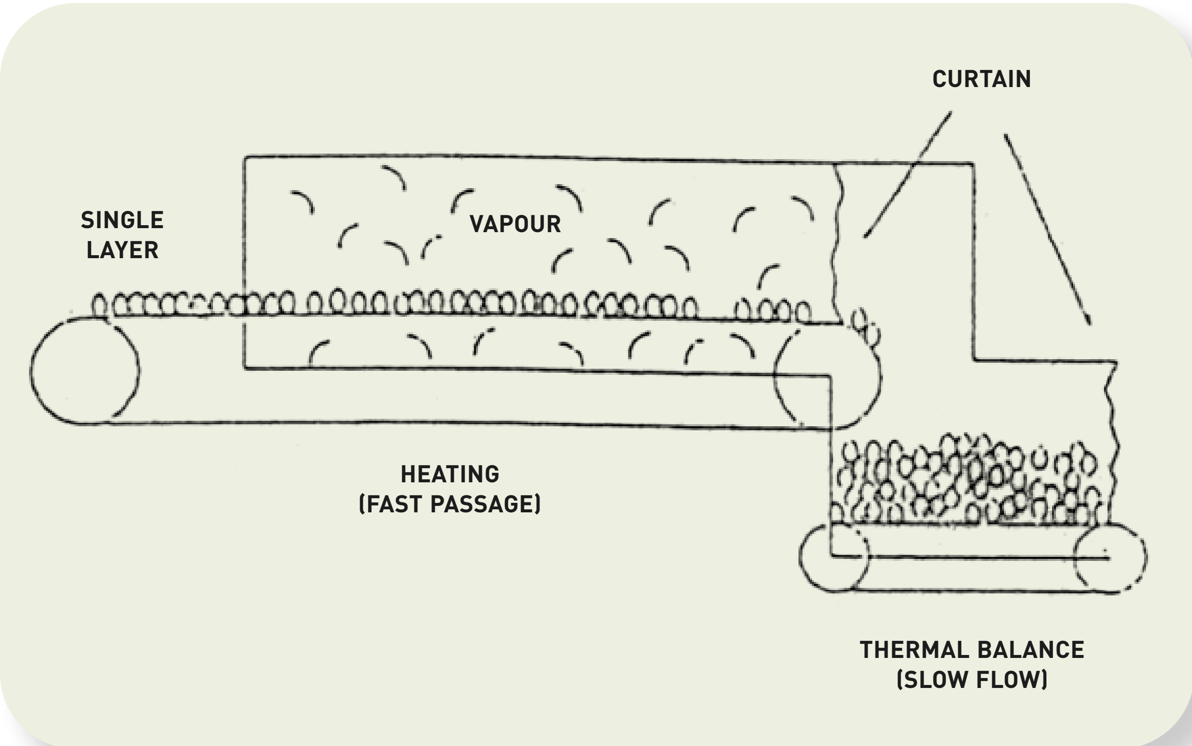
The steam blancher in its most basic form is a simple tunnel fifteen metres long in which the product is carried on a conveyor belt through steam. The time spent in the blancher is regulated by the conveyor belt speed. The manufacturers found a way to improve steam blanchers by improving energy efficiency and increasing heat transfer speed.

Fluidised bed blanchers: A rising mixture of air and steam heated to 95°C is passed over the product and pulsed at 4-5 metres per second. This speed is enough to keep the product bed in suspension. For peas, the blanching time is just 45 seconds. The blanching speed is particularly even and limits the extraction effect and therefore the effluent load. Unfortunately, this technique can only be applied to small vegetables or those cut into small pieces.

The IQB Process *(Individual Quick Blanching)*: Vegetables (peas, cubed carrots, etc.) placed in a single layer, pass through a flow of live steam heated to 100°C (processing time: 30 to 300 seconds). They then fall into an isothermal enclosure (adiabatic chamber which is impenetrable to heat and has no heat exchange with the outside) where they collect onto a slow-moving belt (processing time: 30 to 540 seconds). When in the adiabatic chamber, the product reaches a thermal equilibrium by the diffusion of heat from the surface to the core. Whereas in conventional processes, the exposure to steam lasts until the blanching temperature is reached, in IQB, exposure is much shorter, which can have the following consequences:

- energy-saving
- 40% reduction in outflow volume and 20% reduction in organic matter outflow.

Vegetables in the heating area can be placed on conveyor in a linear fashion, on wire mesh or arranged in a spiral with the vegetables moving by vibration.



Principle of IQP blanching (Cheftel)

As vegetables are arranged in a single layer, IQB blanchers have the disadvantage of being cumbersome on the ground

The effectiveness of blanching can be controlled by inactivating or maintaining the presence of two enzymes, catalase and peroxydase. In practice, the blanching treatment applied ensures that catalase is fully inactivated, but peroxydase only partially so.

3.3.7. Second sorting by quality and size

Although products will have been sorted in the field or upon arrival at the packaging site, they may undergo further sorting by quality and size, immediately before being packaged. In small facilities, the best way of approaching sorting and grading is by using the naked eye and by hand, using a sizing ring or gauges.

3.3.8. Waxing

Applying wax or other coatings (e.g. beeswax – E901–, carnauba wax – E903 –, shellac resin[21] – E904 – and microcrystalline wax –E905) to improve product appearance and limit water loss requires special equipment and is therefore of little interest to small packaging establishments.

Shellac resin

21 Lac secreted from the Asian lac insect, *Kerria lacca*.

3.4. GENERAL RULES OF HYGIENE

3.4.1. Introduction

There is a wealth of documentation and literature on food hygiene, as this field has received much attention, initially from international committees (such as the **joint WHO/ FAO *Codex Alimentarius* Committee**[22]). Today, the *Codex* has more than 20 committees active in specialist areas (hygiene, pesticides, additives, labelling, etc.)[23].

This chapter will not repeat in detail all the specific recommendations relating to hygiene, organisation of work, construction of infrastructure, cleaning and sanitisation of workplaces, personal hygiene, etc., as this is already covered in the *Codex Alimentarius* "Codes of Practice", as well as in Good Practice guides (e.g. BTSF Guide – *Better Training for Safer Food*: Application Guide - Guide to Good Hygiene Practices and HACCP, CE-DG SANCO).

The best option is quote the sources and provide links to documents that can be downloaded, rather than repeat the essential principles in too much detail.

3.4.1.1. General recommendations from the Codex Alimentarius

The *Codex* texts and standards (e.g. MRLs proposed by *Codex*) are **voluntary in nature**. They must be transposed into national legislation in order to be enforceable. Many legal authorities in Member States have legislated on hygiene and other related areas, **often incorporating *Codex Alimentarius'* recommendations into local legislation.**

The general guidelines, codes of practice and rules are the basic texts of the *Codex* and apply to all products and categories of products. They generally cover topics relating to hygiene, labelling, inspection and certification, nutrition and residue from veterinary medication and pesticides.

- The ***Codex* Guidelines** include, in particular, general recommendations for applying the general hygiene principles of food products, such as:
  - principles and guidelines concerning national food control systems;
  - principles and guidelines for microbiological risk management (MRM);
  - principles applicable to product traceability/tracing as a tool for a food product inspection and certification system;
  - principles and guidelines on information exchange between importing and exporting countries to support food trade;
  - principles applicable to inspection and certification of imported and exported food;

  All Guidelines are available at www.fao.org/fao-who-codexalimentarius/codex-texts/guidelines/en/.

---

22 All documents from the *Codex Alimentarius* are available and can be downloaded in PDF format on the FAO website at www.fao.org/fao-who-codexalimentarius/codex-texts/en/.

23 To delve a little deeper, see the recent document "The Science of Food Standards", *Codex Alimentarius*, 2017.

- The ***Codex* Codes of Practice** complement the Guidelines by applying them to specific products. *Codex* has also published general Hygiene Codes of Practice, specific to certain plant products, such as the following:
  - **General Principles of Food Hygiene** (CXC 1-1969, last modified in 2003). They define, for example, the essential principles which are applicable throughout the food chain (from primary production to the end consumer) to ensure that food is safe and fit for human consumption, and therefore forms the basis of all hygiene rules. **Thisis considered to be the most important reference document for food producers and processors**.
  - Code of Hygiene Practice for Fresh Fruits and Vegetables (CXC 53-2003, 2017).
  - Code of Hygiene Practice for Dried Fruits (CAC/RCP 3-1969).
  - Code of Practice for Packaging and Transport of Fresh Fruit and Vegetables (CXC 44-1995).
  - Code of Practice Concerning Source Directed Measures to Reduce Contamination of Foods with Chemicals (CXC 49-2001).

  All Codes of Practice are available at
  www.fao.org/fao-who-codexalimentarius/codex-texts/codes-of-practice/en/.

- **The *Codex* standards** must be transposed into national regulations. The *Codex* publishes a large number of standards for unprocessed fresh and dried vegetable products, but also, for the following:
  - jams, jellies and marmalades (CXS 296-2009, 2017)
  - some canned vegetables (CXS 297-2009, 2015)
  - fruit juices and cordials (CXS 247-200, 2005)
  - fermented pickled fruit and vegetables (CXS 260-2007, 2017)
  - tinned tomatoes (CXS 13-1981, 2017), etc.

  All standards are available at
  www.fao.org/fao-who-codexalimentarius/codex-texts/list-standards/en/

3.4.1.2. COLEACP general recommendations for primary production

The general rules relating to hygiene are covered in detail in COLEACP's handbook, *Principles of Hygiene and Food Safety Management*, particularly chapters 1, 2 and 3.

These chapters describe in more detail the hygiene rules for the production and packing of fresh unprocessed fruit and vegetables, in context, taking into account the working conditions in ACP countries. It is therefore advisable to also refer to it for all matters relating to the following:

- hygiene measures relating to production conditions (particularly production sites and their environment);
- measures relating to personal hygiene (particularly during harvesting operations and primary sorting);
- hygiene measures relating to facilities and equipment;
- water quality control measures;

- hygiene measures relating to transport and warehouse storage;
- traceability[24];
- staff training.

3.4.2. Reminder of the basic rules applicable to all and the whole production chain

Hygiene rules apply to producers, processors, suppliers, exporters, wholesalers, transporters, distributors as well as **in general to any operator within the food chain.** At the other end of the chainthe consumer is also responsiblefor ensuring that their food remains edible and there is no risk of poisoning by handling and storing it hygienically.

Due to a lack of resources or adequate skills, small producers are often unaware of or **significantly underestimate the chemical, biological or physical risks** associated with different stages of the production process. However, even if the origins of some microbial or chemical contamination is not easily predictable and cannot be completely controlled, such as germs travelling by air or atmospheric pollution, it is still possible for all operators active within the food chain to **considerably limit the risk linked to production and packing** by applying a series of basic hygiene measures.

- Rule No. 1

  Fruit and vegetables can be contaminated at any point in the process: during production, handling, transport, packing or storage. Hygiene measures therefore apply at every link in the chain and concern all operators involved in the process, fromthe field to the consumer. Each is responsible for practising the recommended hygiene measures where they cam control the situation.

- Rule No. 2

  With regards to chemical, physical or microbiological contamination of fruit and vegetables, prevention is always better than cure. For products consumed fresh, without cooking or post-harvest processing, the quality of the harvested product is absolutely crucial to the compliance of the finished product Processing products may increase their hygienic quality by destroying some or all of certain micro-organisms, but there will always be some contaminants cannot be completely eliminated.

- Rule No. 3

  An effective food safety management system must include a monitoring and control programme covering the entire production process (farm, packing areas, storage areas, distribution centre and transport facilities). This requires the use of qualified personnel capable of observing recommended good practices and putting in place the necessary regular supervision.

24 Also see COLEACP's manual, *Traceability* for further reading.

- **Rule No. 4**

  The good hygiene practices of employees and sanitary practices at production sites are essential factors in preventing contamination of fresh fruit and vegetables. In terms of biological risks, human or animal excrements are the leading source of contamination of these products by pathogens.

- **Rule No. 5**

  Depending on its source and quality, water can contaminate fresh products that enter into contact with it. This risk of contamination must be kept to a minimum.

- **Rule No. 6**

  Staff training is a precondition for controlling chemical risks. Where chemical risks are concerned, observance of good agricultural practices and correct use of inputs (fertilisers and plant protection products) guarantee compliance with authorised standards.

3.4.3. General hygiene principles in the *Codex*

The general hygiene principles have been described in the *Codex Alimentarius* and have also been covered in several Good Hygiene Practice Guides. They mainly cover **the following points:**

1. Hygiene measures relating to production conditions (the cleanliness of the operating premises, including fields or orchards, sorting rooms, processing rooms, packaging and packing rooms).
2. **Personal hygiene** measures (health status, personal cleanliness, clothing, access to facilities, etc.).
3. Hygiene measures relating to **facilities**: cleanliness of equipment and apparatus (storage material, sorting devices, grading devices, etc.).
4. Aspects relating to product **handling**, transport and storage;
5. Aspects relating to **control of operations** (raw materials, water quality, etc.).
6. Aspects relating to **maintenance**, **cleaning** operations and **waste** management.
7. Finally, in its general principles, the ***Codex* recommends that producers follow the HACCP method,** as a way of improving food safety and provides guidance on how to apply the hygiene principles.

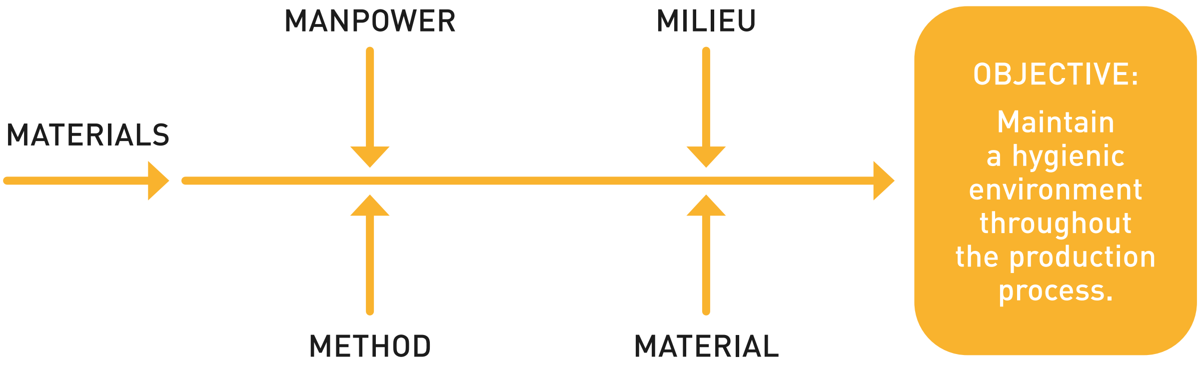
General recommendations on **product traceability** and staff **training** will be added. See the *Codex* documents and Codes of Practice for more information. The *Codex* General Principles also provide guidelines for **drawing up specific hygiene criteria.**

However, each sector in the food chain has products whose characteristics (perishability, sensitivity to microbes, storage conditions) and processes are unique. It is therefore worth each professional sector producing their own **Good Practice Guide** to cover the specific hazards in their sector, the estimated level of risk in their production conditions and the control measures to be implemented as appropriate for the professionals working in the sector.

3.4.4. The overall approach according to the 5 M method.

Hygiene and health quality problems are complex. They require a holistic approach due to the multiple risks that to be managed[25]. To analyse hygiene-related problems, manufacturers often use the **approach known as the 5 M method**or the Ishikawa diagram. This method is used to respond to the following question:

Which parts of the process determine the risk of contamination?



The 5M method (materials (products), manpower, methods of work, materials used, milieu) involves systematically reviewing the factors involved in process hygiene.

- Materials (raw materials)

  Many aspects need to be considered, including the provenance, cleanliness, compliance, labelling and characteristics (e.g. temperature, water content) of products. From our perspective, this not only concerns the **harvested products** (raw ingredients to be packaged), but also the **inputs used** (seeds, water, fertilisers, soil-enriching agents, packaging, phytosanitary products, etc.).

- Manpower

  Everyone involved in handling the products is a potential carrier of **food-borne pathogenic micro-organisms.** Different precautions, therefore, need to be taken in order to minimise risk. Note that hand-washing, as well as personal hygiene, if the first essential step. **Clothing** is also worth mentioning. Most instructions relating to personal hygiene have become commonplace, such as **medical examinations**, wearing an apron, wearing a hairnet to cover hair, or even removing all jewellery before handling food.

- Methods

  This involves all **processes** used for production (**technical itinerary**, from sowing to harvesting), picking, transport, packaging and shipping. Among other things, it is a matter of respecting the GMP, or **Good Manufacturing Practices**.

25 *Codex Alimentarius* Commission - Code of Practice for Fresh Fruits and Vegetables (CAC/RCP 53 - 2003), 26 pages.

- Materials

  Any material (**equipment, utensils and packaging materials**) can contaminate food if it is not properly maintained or fit for use. This involves more than simply washing it properly. The company must also ensure that the staff's list of tasks includes maintaining machines, spreading devices, methods of transport and cold rooms (defrosting, cleaning, sanitisation).

- Milieu

  Work premises, whether the field or packing facility, must be **clean and protected** from pest intrusion. It is essential to ensure, for example that the doors and windows can be adjusted and closed, that the hygiene of the premises and the whole workplace is verified, and that the drainage pipes, waste disposal, ventilation and lighting are all maintained.

3.5. APPLYING BASIC HYGIENE RECOMMENDATIONS OR IMPLEMENTING PRP (PREREQUISITE PROGRAMMES) IN COMPANIES

3.5.1. Definition of PRP

In the food industry, applying the HACCP[26], even in primary production, is **strongly recommended**, as it is considered the universal point of reference on an international scale, in terms of implementing a food safety management system. Today, this type of approach has also been applied to the **phytosanitary fight against** harmful organisms.

However, its application in a company does not in itself guarantee the safety quality of food products. Before considering adopting the HACCP approach in their business, **companies should have implemented Prerequisite Programmes (PRPs)**.

The producer must therefore firstly meet the "basic conditions and activities that are necessary to maintain a hygienic environment throughout the food chain suitable for the production, handling and provision of safe end products and safe food for human consumption" (ISO standard 22000).

PRPs refer to **general** (or cross-departmental) **control measures** which are **not specific to one stage of the manufacturing process**. According to ISO standard 22000, these general measures relate to **10 points**.

1. Construction and lay-out of buildings and associated utilities.
2. Lay-out of premises, including workspace and employee facilities.
3. Supplies of air, water, energy and other utilities.
4. Supporting services, including waste water and sewage disposal.
5. The suitability of equipment and its accessibility for cleaning and preventative maintenance.
6. Management of purchased materials (e.g. raw materials, ingredients, chemicals and packaging), supplies (e.g. water, air, steam and ice), disposals (e.g. waste and sewage) and handling of products (e.g. storage and transportation).
7. Measures for the prevention of cross-contamination.
8. Cleaning and sanitising.
9. Pest control (rodents, insects, birds).
10. Staff hygiene (staff training, personal hygiene measures, clothing rules, management of staff clothing, etc.).

26 HACCP stands for *Hazard Analysis Critical Control Points*. Hazard is used instead of "risk" (as a hazard is an undesirable event, whereas a risk tends to refer to an event which is more llikely to occur.) The HACCP method will be introduced and explained in chapter 5 of the COLEACP manual *Principles of Hygiene and Food Safety Management*. The content will not be repeated here.

The necessary PRPs **depend on the type of company** and the **horticultural sector** or the **part** of the food chain (e.g. primary production, processing, packing, etc.). In the horticultural sector, PRPs can be grouped as follows: Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP), Good Distribution Practices (GDP) and Good Sales Practices (GSP).

Developing as many prerequisite programmes as possible is very useful for the producer and processor, as they are particularly relevant to them.

- They can often avoid the need to use an HACCP plan in the company, which greatly facilitates the management of sanitary and phytosanitary quality. When all relevant hazards are eliminated or avoided at the source using Good Practices, it may mean that there are no Critical Control Points (CCP) to monitor.
- When they are not sufficient to control SPS risks, they should be used as a basis for implementing effective HACCP principles. Putting in place effective PRPs facilitates implementation and allows the number of CCPs to be reduced when studying the HACCP plan. However, in some cases, hazard analysis may result in correcting previously implemented PRPs.

3.5.2. PRP and oPRP

PRPs are sometimes divided into **two categories.**

1. **Infrastructure and maintenance programmes**

The company must **have access to the necessary infrastructure** in order to ensure that products are safe and **to keep them in good condition.** This involves designing and constructing buildings and facilities, particularly workspace and facilities for employees which are suitable for the operations performed (reception, washing, sorting, processing, packaging, storage, etc.). This implies that the supply of air, water, energy and equipment (installation of appliances and accessibility for maintenance) must not affect product safety.

The company must have access to **preventative maintenance, and a cleaning and waste water disposal plan.**

Where applicable, infrastructure or equipment must be modified to take into account the results of any risk assessment tests or have the ability to implement control measures and perform proper maintenance of premises and equipment.

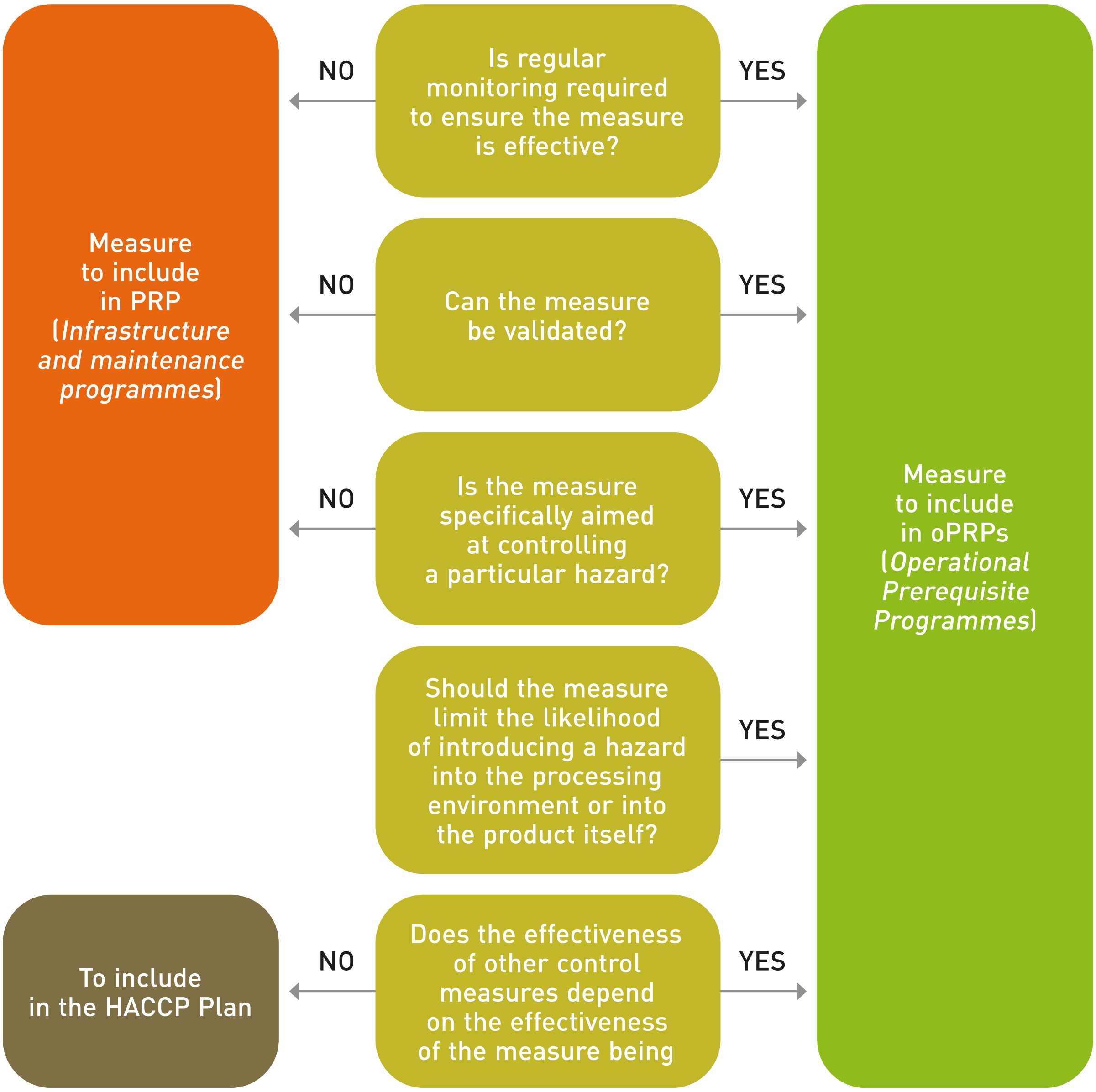
2. **Operation Prerequisite Programmes (or oPRPs)**

The control measures included in the oPRPs must allow the **control of all hazards which are not controlled at the CCP level** determined by the HACCP plan or where no CCP is identified for a hazard (ISO standard 22000).

The following measures must be taken into account in oPRPs:

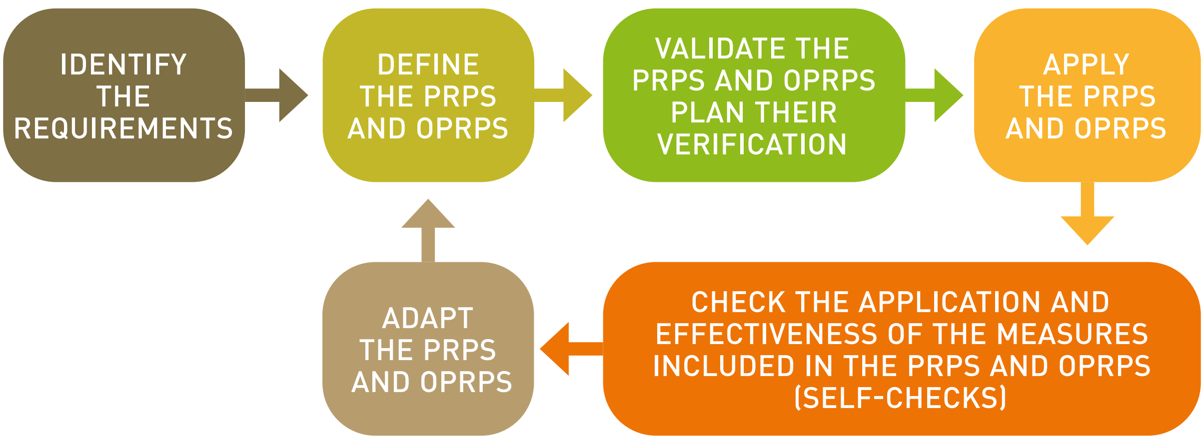
- staff hygiene;
- cleaning and sanitisation;
- pest control;
- measures to prevent cross-contamination;
- packaging procedures and the management of purchased materials (such as raw materials, ingredients and chemicals), supplies (water, air, steam, ice, etc.), disposal (waste and waste water) and product handling (e.g. storage and transportation).

Operational PRPs must be validated and documented using the internal **instructions and procedures** form (company Quality Manual). When the PRP allows a hazard to be controlled to an acceptable level, no CCP is required for that hazard. For example, if the microbiological quality of water used to wash fruit at the packing station is regularly tested, the CCP relating to this operation is removed from the HACCP Plan. In small business, for whom implementing the HACCP is difficult and complicated, respecting the PRP is therefore a useful solution to guarantee product safety. However, **PRPs need to be effective enough** to control the hazard at an acceptable level.



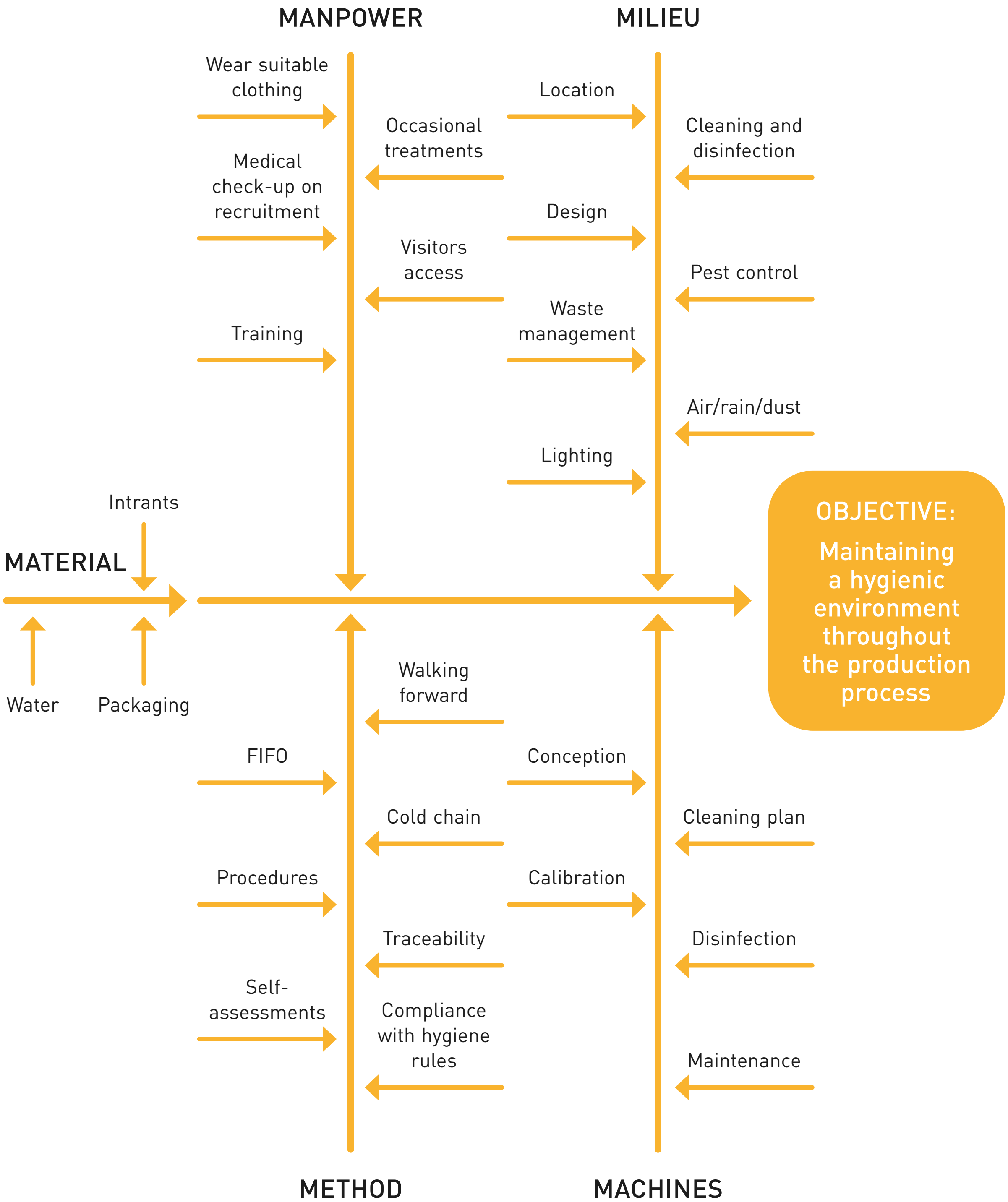
Decision tree for categorising the control measures considered, either in the PRPs, oPRPs, or the HACCP Plan (according to ISO standard 22000)

Furthermore, the PRPs and oPRPs must be recorded in a PDCA (Plan – Do – Check – Act) type overall approach to continuous improvement



3.5.3. The benefits of Good Practice Guides for producers

To implement and control the PRPs, the company itself must identify its own prerequisite programmes based on the *Codex Alimentarius* "General Hygiene Principles of Food Products" or even national, international or industry standards, etc. (e.g. ISO standard 22000). For example, the Ishikawa diagram can be used to identify the measures to include in the PRPs (according to O. Boutou, 2008):



However, as simple as it looks, identifying the source of contamination with this method, as well as determining appropriate control measures, **is not easy, or within the reach of all producers**.

In this case, **the company wanting to implement these Prerequisite Programmes** (in view of the HACCP) **can handily refer to the Good Practice Guides** applicable depending on the part of the food chainand adopt their recommendations.

We will therefore only go over some of the essential rules to guarantee good hygiene.

3.5.3.1. Before the harvest: respect theGood Agricultural Practices (GAP)

Objectives: reduce the likelihood of a hazard compromising food safety or its acceptability for consumption at later stages of the process. Primary production should be managed in such a way that it ensures that the harvested products are healthy, clean and fit for purpose.

The following actions must be taken:

- follow a validated Technical Itinerary (e.g. COLEACP's itinerary), designed with sustainable production systems in mind, which includes combating bio-aggressors.
- avoid production in areas where the environment presents a threat to food safety. Potential sources of contamination by the environment should be taken into account when implementing the Prerequisite Programmes (PRPs) and the HACCP system;
- do not carry out primary production in areas where the presence of potentially dangerous substances would result in unacceptable levels of these substances in food products;
- take measures to combat contaminants, pests and animal disease;
- adopt practices and measures aimed at ensuring that food is produced in appropriate, hygienic conditions.
- use irrigation water which is of an appropriate quality and controlled. Ban the use of untreated waste water;
- comply with the conditions of use of phytosanitary products, particularly the dose, maximum number of uses, the pre-harvest interval (PHI) and the recommended spray volume per hectare (GAP), and work in compliance with the hygiene and safety of staff (following Good Plant Protection Practices aswell);
- ensure that any chemicals used in primary production are registered;
- adopt Good Practices throughout harvesting and sorting in situ (e.g. protect the products from soil contact and heat, and quickly remove products).

3.5.3.2. Post-harvest: followGood Manufacturing Processes (GMP)

- **Avoid risks linked to the environment of sites, facilities and premises**
  - Potential sources of contamination by the environment must be taken into account when implementing Prerequisite Programmes (PRPs) and the HACCP system.
  - Site boundaries must be clearly defined and there should be adequate drainage around the buildings, storage areas and processing areas for (raw) food products.
  - Notably, the previous use of the land, the nature of the soil, erosion, the quality and level of groundwater, the existence of sustainable water sources, the impact on neighbouring surfaces should be taken into account.
  - Access to the facility should be controlled and any potential pest accommodation (such as burrows, subsoil, rubbish) must be removed.

- **Deal with the design and construction of buildings**

  Objectives: comply with good hygiene practices in the design and construction of buildings. An appropriate location and adequate facilities are necessary to effectively control hazards.

  Depending on the nature of the operation and associated risks, the premises, materials and facilities should be located, designed and built taking into account the following requirements.

  - The internal layout and the flow of the production process, products and staff must be logical and designed to prevent any contamination. The "Forward Flow principle" must be followed.
  - High/low risk areas (dirty/clean areas) must be identified and appropriately separated. The layout should ensure that (cross-) contamination of food is as low as possible.
  - The design and layout of the premises must allow for proper maintenance, cleaning and sanitisation, and minimise airborne contamination. The design and construction of buildings must ensure that the dirt and debris is kept to a minimum.
  - Surfaces and materials, particularly if in contact with food, must be non-toxic for their intended use, and if necessary, should be sufficiently durable.
  - The internal structures of the food production building must be built from solid, durable materials, and must be easy to maintain, clean and if required, able to be sanitised.
  - It must be possible to regulate the temperature and humidity, etc.
  - Pest penetration and infestation on the premises should be prevented using effective tools and monitoring.
  - Food products, ingredients and packaging materials must be protected from condensation, leaks, waste, pests and any other source of chemical, physical or microbiological contamination in the design of the facilities.

- Storage areas must be dry and well-ventilated.
- Non-food related chemicals (such as cleaning products, lubricants, fuel, phytosanitary products) must be stored separately in storage bins.
- There should be ample supply of drinking water whenever necessary, with appropriate facilities for storage, distribution and temperature control of the water.
- The water used for post-harvest washing must be drinkable and, if necessary inspected for the presence of contaminants on a regular basis, as appropriate.
- Lighting, whether natural or artificial, should be adequate for operating in hygienic conditions. The bulbs used above the sorting, weighing and storage area must be unbreakable our the lamps must be fitted with a protective cover.

- **Arrange the maintenance and sanitation of sites and premises**

  Objectives: facilitate the effective and continuous control of health hazards, pests (insects, rats, etc.) and other agents likely to cause food contamination. Effective systems need to be in place for the following reasons.

  - To ensure adequate and appropriate maintenance and cleaning. Work spaces and equipment must be properly maintained and kept in good condition to facilitate all sanitation procedures. Any material coming into contact with food products must be made of suitable material and designed and arranged in such a way that it is easy to clean and maintain. The material should be regularly examined and cleaned.
  - Check that the cleaning or sanitisation operations that remove food residue and dirt do not risk contaminating products. Industrial cleaning chemicals must be handled and used carefully, following the manufacturer's instructions.
  - Pest control. Appropriate measures for cleaning, inspection of raw materials and monitoring should be put in place to reduce the risk of infestation as far as possible, thereby limiting the need to use pesticides. Buildings should be kept in good condition and maintained. Holes, drains and other potential points of access for pests should be closed in order to avoid entry and eliminate potential breeding sites. A bait trap must be available.
  - Treat waste and monitor the effectiveness of maintenance and sanitation methods. Appropriate arrangements should be in place to separate, store and dispose of waste.

- **Ensuring staff hygiene**

  Objectives: those who do not observe a sufficiently high level of personal cleanliness, who suffer from certain diseases or conditions, or who behave inappropriately, can contaminate food and transmit diseases to consumers. It is important to ensure that those who are in direct or indirect contact with food do not risk contaminating it by following the following measures.

- Maintain an appropriate level of body cleanliness and behave appropriately. Food handlers must be properly trained and maintain a high standard of body cleanliness. Where necessary they should wear appropriate clothing, hairnets/hats and footwear. Documented hygiene rules, based on the nature of the activities and potential hazards, should be put in place and communicated to staff in the form of diagrams and posters around the workplace.
- Facilities for maintaining personal hygiene (changing rooms, lavatories, wash basins). Sanitary facilities including adequate hand-washing facilities, toilets and adequate changing rooms should be made available to ensure an appropriate level of personal hygiene is maintained and to avoid food contamination.
- Monitor staff health and any injuries. Medical monitoring procedures must ensure that those known or suspected to be suffering from or carriers of a contagious disease or condition are not authorised to enter food handling areas, if there is a possibility that they may contaminate food.
- Food handlers must behave appropriately to avoid contaminating food (no smoking, spitting, eating, chewing, sneezing or coughing near exposed food).
- Wearing personal items, such as jewellery, watches, lapels or other items, or bringing them into food handling areas should be banned.
- Nails must be trimmed, clean and free from nail polish.
- It must be compulsory for staff to always wash their hands before handling food, after handling contaminated products and when leaving the lavatories, to avoid contaminating the product.
- Visitors should be asked to wear protective clothing when entering processing, handling or production areas, if there is a risk of contact with the product.

- **Ensuring and controlling operations**

  Objectives: reduce the risk of dangerous food by taking preventative measures aimed at ensuring food safety at the appropriate stage of the operation by controlling food-related hazards.

  Producing food requires:

  - listing the compliance criteria to be following during the manufacture and handling of specific food products, with regards to raw materials, composition, processing, distribution and end use;
  - designing, implementing, monitoring and reviewing effective control and traceability systems, accompanied by internal and external compliance inspections;
  - managing incoming raw (incoming) materials: no raw materials or ingredients should be accepted if they are known to contain parasites, undesirable micro-organisms, pesticides or toxic or foreign substances that cannot be reduced to an acceptable level by normal sorting and/or processing operations;
  - separating different types of products in order to avoid cross-contamination problems;

- approving all incoming materials and ingredients that may affect the safety of food for its intended use (cleaning products, lubricants, flammable products, pesticides and other substances such as additives). To control food safety hazards, there must be an ongoing procedure in place to select, approve and monitor suppliers.
- implementing appropriate measures, identified by hazard analysis, to prevent foreign bodies entering food (shards of glass, metal, dust, etc.), to avoid excessive heat, and maintain refrigeration, etc.;
- chemicals (additives, cleaning products, fungicides, wax, etc.) must be stored separately in a storage bin and should only be used by trained staff.

3.5.3.3. Post-packing: follow Good Distribution Practices (GDP)

Objectives: in the absence of effective control measures during transportation, food can become contaminated or not reach its destination in a condition that is fit for consumption, even if adequate hygiene measures have been taken throughout the food chain.

Appropriate measures need to be taken during transport and distribution in order to:

- manage products according to the "First In, First Out" principle (FIFO), *i.e.* The product due to expire first is first out;
- protect food from potential sources of contamination;
- protect food from damage that could make it unfit for consumption;
- ensure that the environment effectively prevents the presence of pathogens or decomposition micro-organisms and the production of (myco)toxins in food;
- ensure that the packaging materials used adequately protect the product, in order to minimise contamination, prevent damage and allow for appropriate labelling;
- avoid packaging materials which may be toxic or present a risk to health and safety;
- use reusable packaging which is sufficiently durable and easy to clean;
- have adequate facilities available to refrigerate or store food, depending on the nature of the product;
- appropriately protect food products during transportation in order to ensure their safety. Vehicles and containers must be designed ant built in a way that allows them to be easily and effectively cleaned.

3.6. APPLYING THE HACCP PRINCIPLES

PRPs form the basis for the specific control measures resulting from hazard analysis. Strictly speaking, they are prerequisites. Secondly, hazard analysis allows us to identify relevant hazards to control, the level of control required to ensure food safety and the corresponding combinations of control measures.

The HACCP method was formalised by the *Codex Alimentarius* and applies to all food production, transport, storage and distribution sectors. It allows an operator to identify the hazards that may be present at each stage of the production process, for which monitoring and control are critical to guaranteeing the health and safety of food products. This is why they are known as CCPs, *Critical Control Points*. For each CCP identified, it must be possible to set limits must not be exceeded, to ensure the sanitary quality of the product is controlled. In addition, a CCP may have several critical limits (e.g. temperature and time for pasteurisation).

To be considered a CCP, it must be possible to **continuously monitor** these points of the process in such a way that the results from monitoring may be compared with defined critical limits.

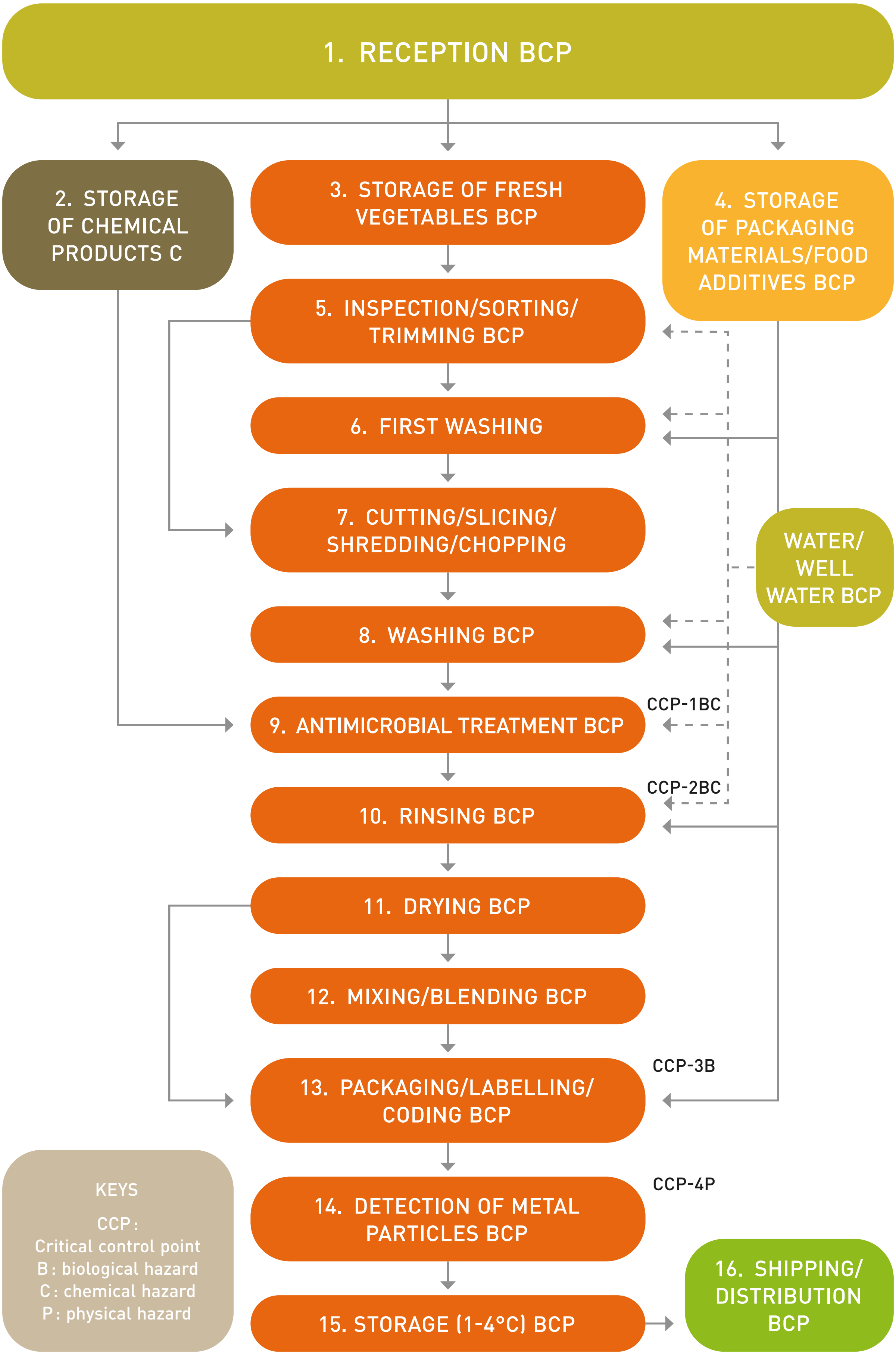
Critical limits are quantitative or qualitative criteria which separate what is considered acceptable from what is unacceptable for food health and safety control. However, **it is not possible to continuously measure** the cleanliness of the operators' work clothes, their level of knowledge of basic food hygiene rules or the effectiveness of the cleaning and sanitisation plan. Furthermore, it would be very difficult to define a critical limit for these elements. These are not therefore considered CCP, but controlling these elements is still necessary to guarantee the health and safety of food. It was therefore important to define a complementary concept to the CCP, hence the prerequisite programmes (PRPs).

The 7 principles and 12 stages of the HACCP approach are explained in detail in the COLEACP handbook, *Principles of Hygiene and Food Safety Management*, namely chapter 5. It is advisable to consult this, as required.

The HACCP system is based on the following seven principles (*Codex Alimentarius*).

- Principle 1: Analyse the risks
  Identify the potential hazard(s) associated with each stage of the food chain from primary production, to handling, processing and distribution, right through to consumption. Identify the probability of hazards arising and identify measures to control them.
- Principle 2: Identify the critical points to be controlled (CCP)
  Identify the handling points, procedures or stages which can be controlled, in order to eliminate the hazard(s) or minimise the likelihood of it occurring. A "stage" refers to any food production and/or processing stage including approval and/or production of raw materials, harvesting, transport, preparation, handling, storage, etc.
- Principle 3: Set the critical limits (thresholds)
  Set the critical limits to be adhered to in order to ensure that the CCPs are always under control.
- Principle 4: Put in place a monitoring system to control the CCPs.
  Create a monitoring system to control the CCPs using observations and programmed tests.
- Principle 5: Identify the corrective measures to be taken when monitoring reveals that a given CCP has not been controlled.
- Principle 6: Apply the verification procedures in order to confirm that the HACCP system is working properly.
- Principle 7: Produce a file including all the procedures and records on these principles and their application.

Using a production flow chart, the HACCP team can apply hazard analysis and identify the CCPs.



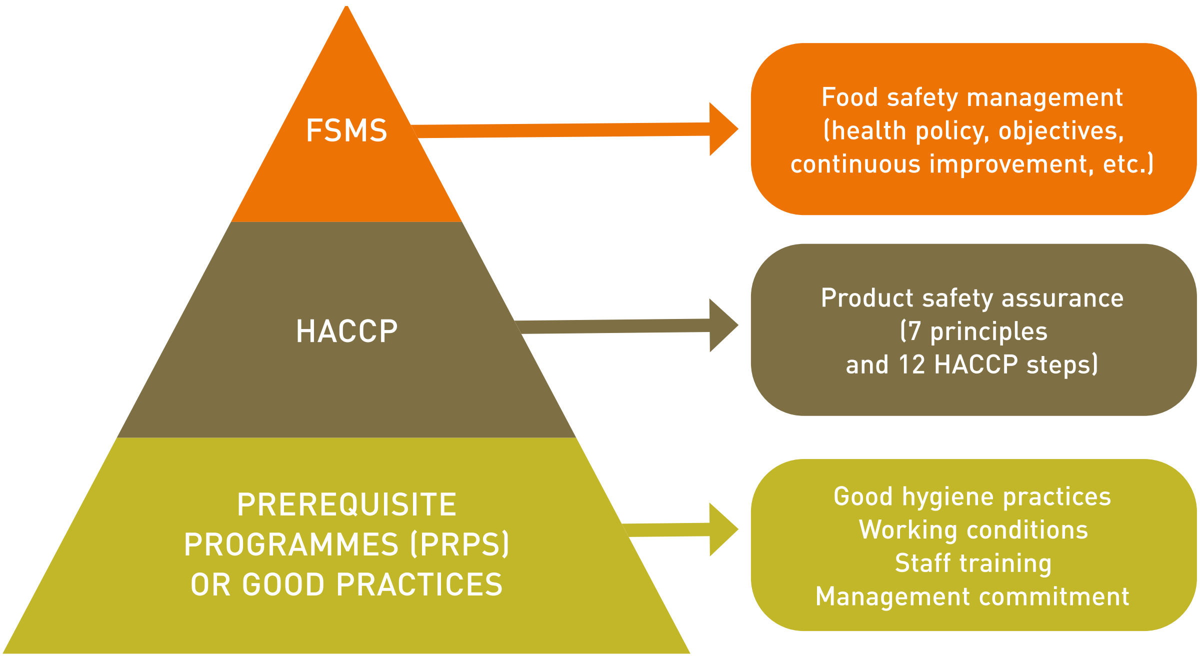
Example of a production diagram using an HACCP Plan.
Different types of hazards and four CCPs have been identified in this example.

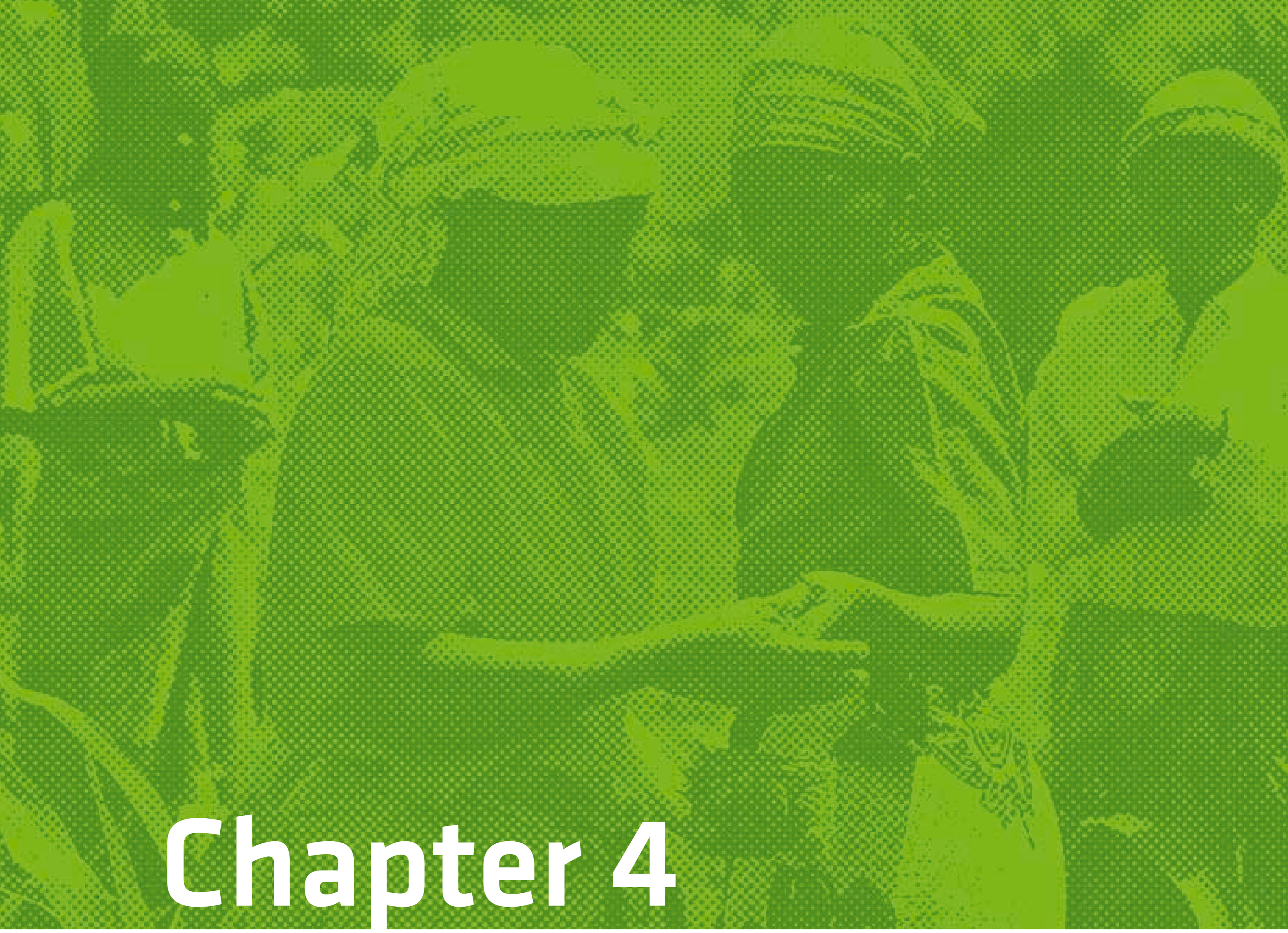
3.7. IMPLEMENTING A FOOD SAFETY MANAGEMENT SYSTEM (FSMS) IN A BUSINESS

The PRPs work best and the HACCP results will be more sustainable if they are used within the context of a Food Safety Management System (FSMS), including traceability.

Implementing a FSMS requires the full commitment and involvement of all management and staff, a policy, objectives, data analysis and a regular review of the management system.

Managing the health and safety of food is therefore based on a pyramid, the base of which is made up of Good Practices (PRPs), as shown in the following diagram:





Chapter 4

Food preservation techniques

4.1. GENERAL PRINCIPLES

4.1.1. Definition and benefits of preserving fruit and vegetables

Food preservation includes a whole host of processing procedures which aim to **preserve the flavour and nutritional properties, texture and colour** of food products, as well as their **edibility** and to **avoid potential food poisoning**. The main aim of preservation is therefore to delay the spoilage of food and avoid changing its taste, or sometimes its appearance. This objective can be achieved in a number of ways using treatment processes, such as canning, dehydration (drying), smoking, refrigerating, packaging and the use of additives, such as antioxidants and other preservatives.

Preservation is generally defined as a method used to preserve the current state or to prevent spoiling likely to be caused by chemical (oxidation), physical (temperature, light) or biological (micro-organisms) factors. By preserving food, we are able to have access to it between harvests. Preservation usually involves the following:

- delaying oxidation of fats causing rancidity or auto-oxidation and autolysis by the food cell's own enzymes;
- preventing the development of bacteria, fungi and other micro-organisms;
- animal pest control, particularly against insects and rodents.

Food preservation therefore concerns **all biological** (micro-organisms, animals, plant germination, etc.) **and abiotic** (light, oxygen, heat, irradiation, UV, etc.) factors which can degrade the quality of the stored food.

Numerous techniques are used to preserve food, from the most simple (e.g. **preserving food naturally**, e.g. by putting it in the garden over winter, keeping it at room temperature, in a rack or silo; preserving by **adding olive oil, vinegar, sugar, alcohol or salt**) to the more sophisticated techniques in terms of control, equipment and energy consumption (e.g. **preserving by cooling** using refrigeration or freezing, and **preserving by heating** by pasteurising or sterilising. These techniques emanated from the need to store food in times of abundance and plenty, to avoid scarcity or famine during less prosperous seasons (end of winter, a year with low yields, etc.). Later, some preservation techniques joined the ranks of high-end products (e.g. lacto-fermentation, jams, chutneys, etc.).

Some products do not require this preservation technique and keep by themselves, whereas others perish quickly. For example, dried fruit, nuts and hazelnuts, as well as seeds, can be stored in a cool dry place (such as a barn or attic) without spoiling, and keep for about a year or even longer (as long as they are protected from rodents, insects and birds, etc.). Some fleshy fruit, such as apples, can keep for several months on the tree (as long as they are picked carefully at the time of harvest).

Industrial development went hand in hand with the development of transport (e.g. air freight) of food between producer and consumer regions, thereby reducing the need for preservation in some cases. Eating fresh pineapple is more pleasant than eating tinned products. Processing does not necessarily mean the product is better quality or better value.

4.1.2. Which principles form the basis of the different preservation techniques?

All preservation methods aim to **prevent micro-organisms from accessing one of the main essential elements required to survive** (food - a source of carbon, a source of nitrogen, a source of sulphur, vitamins, mineral salts, etc., water, heat or oxygen, except for anaerobic bacteria). Once the micro-organisms have been denied access to these elements, they must be prevented from regaining access, otherwise the spoiling process will begin again. They must be "preserved" as they are.

Depending on the food and the methods available, **different techniques** can be used to preserve food. Common food preservation methods include drying or dessication, freezing, vacuum-sealing, pasteurisation, canning, irradiation and adding preservatives. Smoking adds chemical compounds which inhibit micro-organisms. Vacuum-packing reduces the air quality and therefore the action of oxygen. Adding vinegarmakes it acidic., Adding sodium hydroxide (soda) makes it too alkaline for bacteria to grow. Cold preservationslows or inhibits the development of micro-organisms, and heating can kill them (completely or partially, depending on the temperature and duration of treatment).

Other methods **not only help the food to keep, but also add flavour**, such as salting, jam, ketchup and smoking. Fruit-based sweets and fruit jams use the preserving qualities of sugar (candied fruit loses most of its compounds which are replaced by sugar).

4.1.3. Main preservation techniques

Preservation techniques can be grouped into **4 main categories**, each containing several variations.

- **Preserving by dehydrating food**. Dehydrating reduces the amount of water available in the food. This is without doubt the oldest technique.
  - **Drying**, in the sun or in an oven. Products can simply be laid out or sliced or dried as they are (mangos, figs, dates, grapes, etc.), possibly treated with a food oil to limit oxidation (e.g. dried tomatoes).
  - **Freeze-drying** is a dehydration technique which involves sudden freezing (between approximately -40°C and -80 °C) with vacuum sublimation. Food preserves all its flavour as well as its nutrients. Once rehydrated, it regains almost the same original texture. This technique creates good quality products which rehydrate well, but remains expensive.

  This technique has multiple benefits. The water activity of the treated product reaches sufficiently low values to inhibit the development of micro-organisms and stop enzymatic reactions. The reduction in weight and volume means a lot of space is saved in packing, transport and storage. However, following dehydration, **specific storage conditions are required** to avoid regaining humidity too quickly, such as a silo, leak-proof packaging, inert gas or vacuum packing.

- **Preserving by heating.** The result of the heat treatment applied defines the specific type of heat preservation and whether it is pasteurisation or sterilisation.
  - **Pasteurisation** is a technique which involves heating food to a temperature between 65 and 100°C and then cooling it quickly.
  - **Canning**, which was invented by Nicolas Appert in 1795, allows food to be preserved in watertight containers for a long period of time without requiring any specific storage conditions (particularly temperature). This process requires **sterilisation** (heating to between 115°C and 121°C), which requires very strict control of temperature.
  - Preparing jam combines two preservation processes: heat treatment (boiling for a few minutes) and mixing fruit with sugar. The jars need to be boiled before filling to the brim to avoid mould forming.
- **Preserving by cooling**: Cold treatment slows down and can even stop the proliferation and action of micro-organisms, and preserves the food a fairly long period. There are several techniques of this kind.
  - **Refrigeration**: Lowering the temperature (to between 4 and 8°C) reduces the action of bacteria and enzymes present in food. It preserves food for four to six days.
  - **Freezing**: this technique involves lowering the temperature of food and keeping it below the melting point of ice (0°C). In practice, (in freezers) this is between 0 °C and -15/-18 °C. If the cooling speed is fast, some ice crystals form and the cell tissue is maintained. This means food can be consumed several years after it was frozen, if not defrosted.
  - **Flash freezing** is a technique that involves fast cooling (to -18/-196 °C) followed by freezing at -15/-18 °C.
- **Chemical preservation** combines several techniques.
  - **Preservationin dry salt** (salting) or brine (brining) or using saltpetre (keeps the sulphites). Salted, hard and discoloured food must be desalinated before consumption. This technique reduces the water activity and is mostly used for fish and meat (charcuterie, etc.).
  - **Preserving in an acidic environment**, such as vinegar. The acidity changes the appearance and texture, in addition to reducing the flavour and amount of vitamins (e.g. in cornichons, onions etc.) in food. Colourings and salt are added to enhance flavour.
  - **Preserving in alcohol.** The original organoleptic qualities and vitamins are lost, as with candied fruit. This method is mainly used for fruit.
  - **Preserving in sugar** (sugaring). As sugar is very hygroscopic, it does not allow bacteria to grow. This method is mainly used for fruit (jam, syrup, etc.).
  - **Preserving in oil** (tomatoes dried in oil).

  Note that there are other techniques in this category (smoking, preserving in fat, preserving by adding food preservatives), but these are not strictly relevant to preserving fruit and vegetables.

There are other techniques which are used more rarely (sometimes used for certain high value products), such as using **vacuum-packing** or **modified atmosphere packaging** (nitrogen, carbon dioxide).

Not all preservation techniques are created equal, not only in terms of nutritional value (e.g. preserving vitamins), but also in terms of preparation, storage, energy consumption, maintaining the original taste, or even for ease of use. Each method has its advantages and disadvantages.

Below is a summarised assessment positive (green), average (orange) or negative (red) for each technique

	Preservation of vitamins	Energy required	Preservation of flavour*	Ease of use**
Room temperature, rack, silo	🙂	🙂 🙂	🙂 🙂	🙂 🙂
Freezer (raw food)	🙂	☹️ ☹️	🙂 🙂	🙂 🙂
Drying	😐 (acidic fruit, mushrooms) ☹️ (vegetables)	🙂 🙂 (solar) ☹️ (artificial)	🙂	😐
Sterilisation	☹️ ☹️	☹️ ☹️ (preparation)	🙂 😐	🙂
Oil	😐	☹️ (preparation)	😐	🙂
Vinegar	😐	🙂	☹️	🙂
Sugar	☹️	🙂	☹️	🙂
Alcohol	😐	🙂 🙂	☹️	🙂
Salt	😐	🙂	☹️	🙂
Lacto-fermentation	🙂 🙂	🙂 🙂	☹️ ☹️	🙂 🙂

* If the flavour is not preserved it does not mean that it has gone bad, but simply that the taste of the fresh food varies quite strongly. Fermented cabbage tastes very different to raw cabbage, and it doesn't necessarily mean that it isn't as good.

** Equipment required, time taken, complexity, etc.

4.2. PRESERVING BY DRYING

4.2.1. Drying fruit

Drying is one of the oldest preservation techniques. The humidity level of agricultural products is lowered to 10 to 15%, which prevents micro-organisms from multiplying and inactivates enzymes. The dehydration process does not generally go any further than this as the products would become brittle. To prevent food from becoming damaged once dry, it is stored in a dry place.

In theory, drying is easy to perform. When products lose water, they become lighter, making them easier to transport. However, there are also disadvantages. The food loses vitamins and its appearance changes.

The most modern drying method involves exposing products to the open air. The air absorbs the water and the hotter it is, the more water is absorbed. For best results, the air should be warm, dry and flowing.

In a closed environment, the air should be renewed regularly to prevent it becoming saturated with the moisture it has absorbed from the products. It is therefore important that the room is well-aired. The relative humidity (RH) level should be below 65%. If this is not the case, fruit and vegetables will be dried, but not the way they should be. When the sun is out, the RH level is generally below 65%, but if it is cloudy or particularly if it is raining, it tends to be higher. It is therefore very important that the sun is out. This is why products cannot be dried this way all year round.

Before being processed, fruit and vegetables are carefully washed and then chopped. It is sometimes necessary to prepare them so they keep their colour and to minimise nutrient loss. The quality of the dried product will depend on a number of factors:

1. the quality of the processed product,
2. how the product has been prepared,
3. the drying method used,
4. the packing and storage conditions.

4.2.1.1. The quality of fresh produce

Fruit and vegetables to be dried must be of good quality. Rotting or damaged fruit should never be mixed with healthy fruit. To avoid products losing their quality, they must be **dried as quickly as possible after being picked**. Firm fruit and root vegetables can last longer than more tender fruit and leafy vegetables. The time between harvesting and consumption is usually the maximum time between harvesting and drying.

4.2.1.2. Preparation

Washing and chopping

Carefully wash the fruit and vegetables. Remove any sand, stains and seeds. Fruit which is peeled and chopped dries quicker. It is important that all pieces are the same size so that they dry at the same speed.

Tubers and root vegetables should be chopped into slices 3 to 6 mm thick or into 4 to 8 mm pieces. Leafy vegetables like cabbage are cut into pieces 3 to 6 mm thick.

4.2.1.3. Natural drying

Drying in the open air is a simple and inexpensive process. It doesn't require any costly energy, just sun and wind. The product to be dried is placed in thin layers on trays or black plastic and exposed to direct sunlight. The trays are usually made of wood and lined with plastic or galvanised nets. The trays should be placed 1 metre above the ground on stands set on a flat surface. This way no dirt can come in contact with the food from below and the food can receive maximum sun exposure.

If necessary, the trays can be covered to protect the food from rain, dust, birds, insects and other pests. Mosquito netting offers the best protection from pests. To ensure that the fruits or vegetables dry uniformly, it is best to turn them regularly or at least to shake the trays every now and then. This does not apply to tomatoes, peaches or apricots, which are cut in half and arranged in a single layer on the trays.

Fruit dries very well in the sun, but some products are damaged by exposure to direct sunlight and therefore take better to drying in a shaded spot. Beans and (red) peppers, for example, are bunched and hung up under some type of shelter. Drying these products obviously takes more time.

In areas with a high chance of rain, it is advisable to have an artificial dryer that can be used when it is raining or when the RH is too high. This will prevent the drying process being interrupted and subsequently also a loss of food quality. In the event of rain, the (moveable) trays should be covered with plastic or placed under a shelter. Afterwards, they should be returned as soon as possible to the drying spot. It takes about two to four days to dry tropical vegetables.

4.2.1.4. Artificial drying

The temperature of outside air often needs to be increased only by a few degrees to make drying possible. For example, during a rain shower at 30°C the air must be heated to at least 37°C to be able to dry fruits or vegetables. Heating it further increases the speed at which the product will be dried because of the following:

- the air can absorb more water;
- the product releases water faster at higher temperatures.

The air can be heated with solar energy or by burning natural or fossil fuels. The maximum drying temperature is important because above this temperature the quality of the dried product deteriorates rapidly. Another reason for not drying at very high temperatures is that the product then dries quickly on the outside, but remains moist on the inside.

4.2.1.5. When is the drying process finished?

To test whether a product is sufficiently dry, it first has to cool down. A warm product is softer and seems to contain more water. Fruit may contain 12-14% water; vegetables should be dryer, containing 4-8% water depending on the type, as vegetables contain less sugar. The moisture content is difficult to measure without a drying oven or moisture content meter. However, the following can be used as general guidelines.

Fruit

- If you squeeze the fruit, the juice should not seep out.
- The fruit must not be so dry that it rattles when the drying trays are emptied.
- It should be possible to mix a handful of fruit pieces, but they should not stick to each other.

Vegetables

- Greens should be brittle and easily rubbed into a powder.

4.2.1.6. Packaging and storage

At the end of the drying period all foreign material (stems, etc.) should be removed, as well as pieces that are not yet dry enough. Dried vegetables can easily absorb water from the surrounding air because of their low water content, so packing has to take place in a dry room. It is a good idea to finish drying during the warmest part of the day when the relative humidity is at its lowest. The product can be cooled in the shade and if the work has been done hygienically, the cooled products can be packed immediately.

The packing material must be waterproof, airtight and insect-proof. The dried products will only keep their quality if stored in such a way that they are dry and protected from insects. Normal plastic bags (properly sealed) will do for some time, but are not entirely gas and waterproof. It is also possible to use polymer-coated cellophane bags, which are water and airtight. These can be closed with a hot iron or a sealing machine (where electricity is available). Unfortunately, this kind of plastic is not as easily obtained, and it is not very strong.

It is better to use a thicker plastic bag (polyethylene, 0.05 mm thick). These can be closed tightly with a metal clip or with adhesive tape, although the quality of the closure also depends on the force with which the bag is closed and on the flexibility of the material. The plastic bags still have to be stored in a cool place and must be protected against rats and mice. It is therefore better to put a number of small bags in bigger jars or tins, which can be closed tightly as well. Using small bags stops the product absorbing water despite regular opening of the tin. Each bag can best be filled with a quantity sufficient for one family meal.

Gourds can also serve as a packing/storage material. They must be closed well and smeared with linseed oil, varnish or other sealing material. Ground products absorb water quicker, so it is wise to grind them just before use, rather than storing the products in ground form. Properly dried and packed vegetables can be stored for about one year. After that, the quality can deteriorate rapidly. Cool storage (e.g. in a cellar) makes longer storage possible.

4.2.1.7. Examples

Drying tomatoes

Use firm tomatoes which are not damaged or too ripe. Wash and then cut them in half or in quarters (or in smaller pieces), then remove the seeds. Blanch the tomato pieces for one minute at 90°C and then allow them to cool off quickly under cold, running water. Once cooled, they have to be immersed for 10 minutes in water containing lemon juice. Strain and then dry them with a clean cloth. Place the tomatoes on a piece of black plastic and leave them to dry in the sun. To make sure that they dry evenly, turn them 2 to 3 times per day. Bring them under cover in the evenings. After 2 to 3 days they will feel brittle and the drying process will have been completed.

Drying mangos

Use firm, ripe mangos. The varieties Ameli and Kent are particularly good for drying. Wash and peel the mangos and then cut them in pieces about 6-8 mm thick. You can then choose to either blanch them in water at 56°C with two tablespoons of lemon juice added per litre of water, or immerse them in a 40% sugar solution for 18 hours, with the same amount of lemon juice added. In both cases, add 3 grams of sodium bisulphate ($Na_2S_2O_3$) per litre of water to prevent the fruit from discolouring and to protect it from mould and insects. After this preparation, the pieces of fruit should be briefly rinsed with hot water to keep them from sticking together. Finally, place the mango pieces to dry on trays, preferably made of plastic mesh (metal trays cause food products, especially fruit, to discolour quickly) and coated with glycerine to prevent sticking.

4.2.2. Drying starchy tubers and onions

The method used to dry tubers is completely different to that of onions.

4.2.2.1. Drying root vegetables and tubers

Drying root vegetables and tubers replaces and strengthens the damaged parts of the rough skin, and protects it against water loss again and infection by decomposing organisms. The main crop of this type which is dried is the potato, but some root vegetables and tropical tubers are also dried.

Although details of the operation vary depending on the product, **the following conditions must always be met.**

- Root vegetables and tubers must be kept at an appropriate temperature, usually slightly above room temperature, in order to stimulate new skin growth.
- The atmosphere must be kept moist, but without free water on the surface of the root vegetables or tubers; No new skin will be formed in dry air on injured surfaces.
- Some ventilation is needed for new skin growth, but excessive air flow will dry out the atmosphere and cause a drop in temperature.

- The temperature must be kept steady. If it falls, condensation will form on the surface of the vegetables, which will encourage bacterial rot.

As almost all root vegetables and tubers are damaged in some way during harvesting and handling, **they must be dried as quickly as possible**. This can be done by limiting ventilation, which allows the temperature to rise sufficiently to promote drying. At the same time, the air will take on moisture due to the normal water loss of the root vegetables and the high evaporation rate from the damaged areas.

While the storage conditions for potatoes are well known, those of **tropical root vegetables** are mainly based on experience. The shelf life of sweet potatoes and aroids, such as taro and yam, is generally quite short, as they are sensitive to decay after harvest. Cassava becomes discoloured on the inside and decomposes rapidly.

Suggested method for drying root vegetables and tubers

Crop	Temperature (°C)	Relative humidity	Drying time (days[1])
Potatoes	13-17	Over 55%	7-15
Sweet potato	27 33	Over 90%	5-7
Yam	32-40	Over 90%	1-4

1: In practice, you should plan for seven days of drying

4.2.2.2. Drying onions

Onions are immediately dried after picking. In hot, dry weather, the harvested onions are left on the ground for a few days until the green stems are completely dry. In wet weather, the onions are dried on racks or trays under cover. Onions need to be dried for the following reasons:

- The neck of onions is very prone to decay if it remains wet, especially if the green stems are cut before harvest;
- drying the outer layer of the bulbs limits decay and water loss;
- Any roots which have been damaged during harvesting often provide a site of decay if not immediately dried.

Cutting the green stems of onions is not recommended for smallholders, as it greatly increases the risk of loss through decay if the bulbs are not quickly dried in a controlled environment. At large, commercial farms, where the green stems are cut by machine before harvesting, onions are always dried in artificial heat with forced ventilation. This process is too costly for artisanal producers.

Onions dried in the field can be stored for up to a maximum of two months at room temperature on well-ventilated trays placed on palettes, or even remain in the field attached to a windbreak. Dried onions should never come into contact with wet soil.

4.2.2.3. Preventing sprouting

Sprouting potatoes and onions is a problem in countries where they can be stored for up to eight months. Prolonged storage may not be necessary in warmer climates where producers generally harvest several times a year.

Two methods are used to prevent sprouting.

- Selecting varieties with a long dormant period. Seed and plant supplies may be asked to provide information on the storage characteristics of locally-produced varieties.
- The use of chemical plant growth regulators for potatoes and onions in storage. Some plant growth regulators need to be applied before harvesting (e.g. maleic hydrazide). Others are mixed in powdered or granule form with potatoes at the time of storage. Plant growth regulators are rarely used, except in large production and storage companies. They should only be applied after consultation with agricultural extension workers.

4.3. PRESERVING BY HEATING

4.3.1. Introduction

One of the most common and effective ways of preserving fruit and vegetables is toprepare them and **place them in air-tight containers, which are then heated.**

The high temperatures ensure that micro-organisms are killed and the enzymes inactivated. Any remaining spores won't be able to develop into bacteria and the food will be protected from any external microbial contamination. However, it is important to remember that **some micro-organisms are unfortunately less sensitive to heat**: *Clostridium* and *Staphylococcus* can still multiply and spoil the food through the poisonous substances they produce. ***Clostridium* can cause botulism** and result in tragic deaths. **This bacteria has difficulty growing in acidic products such as fruit (pH <4.5).**

The heating method for fruit is different than for most vegetables. As noted above, fruit has a low pH level. It can be heated in boiling water (100°C), whereas most vegetables have to be heated at temperatures above 100°C, because they have a higher pH and are thus more susceptible to bacterial contamination.

This preservation method produces the best results, but only if **fresh products** are used and the instructions for heating are followed exactly. As with other methods, heating has advantages and disadvantages as outlined below.

Advantages

- Most micro-organisms are destroyed so there is less chance of spoilage.
- After being sterilized and stored, the food can be kept longer and more safely.

Disadvantages

- Heating requires the following investment:
  - heat-resistant storage containers (which can be difficult to obtain) such as cans or glass jars. The latter are preferred because they can be reused.
  - cooking utensils, such as a steamer;
  - fuel.
- These investment expenses will have to be recovered from the final cost of the product.
- This method is labour intensive.
- It requires access to plenty of water.

Preserved fruit and vegetables have a **lower nutritional value** and generally less taste than **fresh products**. However, fewer nutrients are lost using the heating method than in any other preservation method.

Pasteurisation and sterilisation are two heating methods used to prevent food from rotting and to prepare it for storage in glass jars or tins.

4.3.2. Preparation and processing methods

Before a product is heated in its storage container, it needs to be prepared. If it is well-prepared the whole operation is bound to succeed. There are 3 processing methods for preserving by heating:

1. Pasteurisation (heating up to 100°C) – for products that will be subsequently stored at temperatures below 20°C;
2. Sterilisation at 100°C - for acidic products;
3. Sterilisation (above 100°C) in a pressure cooker or an autoclave (large pressure cooker).

The food to be preserved is usually heated in a large pan and then **packed while still hot**. This is the most efficient method, because it is **faster** to thoroughly heat a large amount of food in a large pan by continually stirring than to heat smaller amounts of food in individual sealed bottles or tins. **It takes much more time for the heat to penetrate to the centre of the food in the jars.**

The cans or jars must be filled to 0.5 cm from the rim. For leafy vegetables, the liquid must first be poured away, then the vegetables added. **Make sure as many air bubbles are removed as possible. The closing temperature is very important.** Always measure the temperature in the middle of the container. Quickly close the container and heat according to the recommendations. Place the bottles or jars in water before it reaches boiling point as sudden exposure to a hot temperature will cause the glass to crack. Cans, however, can be placed directly into boiling water.

4.3.2.1. Pasteurisation

Pasteurising is a **mild heating treatment at temperatures up to 100° C** (which is the boiling point of water at altitudes up to 300 metres above sea level). This method causes only a slight decrease in taste and nutritional value. The enzymes are inactivated and most, but not all, bacteria are killed. **Pasteurised products therefore spoil faster than sterilised products.** To prevent the surviving spore-producing micro-organisms from multiplying, **the products should be stored in temperatures below 20°C.**

To extend the shelf life of fruit preserves, a lot of sugar is often added, which allows them to remain edible for months. **The more acid or sugar contained in a pasteurised product, the longer it will keep** because the remaining micro-organisms do not have a chance to grow.

A product is pasteurised by heating it for a time in a closed glass or tin in a pan of hot water. **It is important that the lids of glass jars fit well, but they should not be twisted tightly closed, because some air should be allowed to escape while being heated.** However, the lid should be tightly closed immediately after removing the jar from the pan. As the product cools, a vacuum will develop within the container, preventing the food from coming in contact with the air and becoming contaminated. The water in the pan has to be warm and at least the same temperature as the filled bottles and tins. Remove the bottles or tins as soon as the recommended time has elapsed and allow them to cool.

Remember that the boiling point of water decreases as elevation increases[27]**.** In areas up to 300 metres above sea level the boiling point is 100°C. At higher altitudes the heating time will have to be increased as indicated in the following table in order to compensate for the lower boiling temperatures.

Sterilisation time at different altitudes

Altitude in metres	Sterilisation time in minutes	Example
0 - 300	a	a = 10 minutes
300 - 600	a + 1/5 a	total 12 minutes
600 - 900	a + 2/5 a	total 14 minutes
900 - 1200	a + 3/5 a	total 16 minutes

Since pasteurisation sometimes requires heating to 100°C and the food can only be kept for a limited time, it is better not to pasteurise food at altitudes higher than 300m, but to sterilise it instead (possibly under pressure). Products that have to be heated to temperatures below 100°C can be made at higher altitudes, as long as the required temperature can be achieved.

Fruit juices have to be pasteurised at temperatures between 60 and 95°C.

Canned vegetables should always be cooked for 15 minutes before eating.

27 This point is important to remember when considering an HACCP Plan, as the heat processing operation is a CCP. A general temperature recommendation cannot therefore be given, as the boiling temperature may vary depending on the geographical location of the facility.

4.3.2.2. Sterilisation in a bath of boiling water

Sterilisation involves heating products to over 100°C. This process kills all the micro-organisms, **but not the spores they produce.** Under the right conditions, these spores can grow into bacteria which spoil food. As spores do not grow well in acidic conditions, **acid is often added** to the preserved food. **Sugar has the same preventative effect.**

Therefore, by adding sugar or acid to a product, you can ensure that the sterilised product will keep for a long time.

Put the tins or glass jars into a deep bath of hot water. Monitor the time from when the water begins to boil. The boiling point depends on the altitude. At altitudes above 300 metres, the boiling time needs to be adapted according to the table. Cool the containers in fresh cold water, which is regularly refreshed to speed up the cooling process. Wait until the jars have cooled down before placing them in cold water.

4.3.2.3. Sterilisation with a pressure cooker or autoclave

Sterilisation carried out properly in an autoclave or pressure cooker **will kill not only micro-organisms, but also the spores. Food will have a longer shelf life without needing to add acid or sugar.**

In an autoclave or pressure cooker the boiling point of water is at a temperature higher than 100°C. If the atmospheric pressure (at sea level) is increased by 0.7 bar, then the water in this type of pan will boil at 115°C; if the pressure is increased by 1 bar **the boiling point becomes 121°C.** Here too, the boiling temperature is lower the higher above sea level you are. This reduction can be compensated for by increasing the pressure by 0.1 bar for every 1000 metres above sea level. To sterilise canned vegetables the temperature is allowed to reach 115-121° C. In general, all foods with a high pH (which includes most vegetables) have to be sterilised at a temperature above 100°C. We recommend that a pressure cooker be purchased for this purpose.

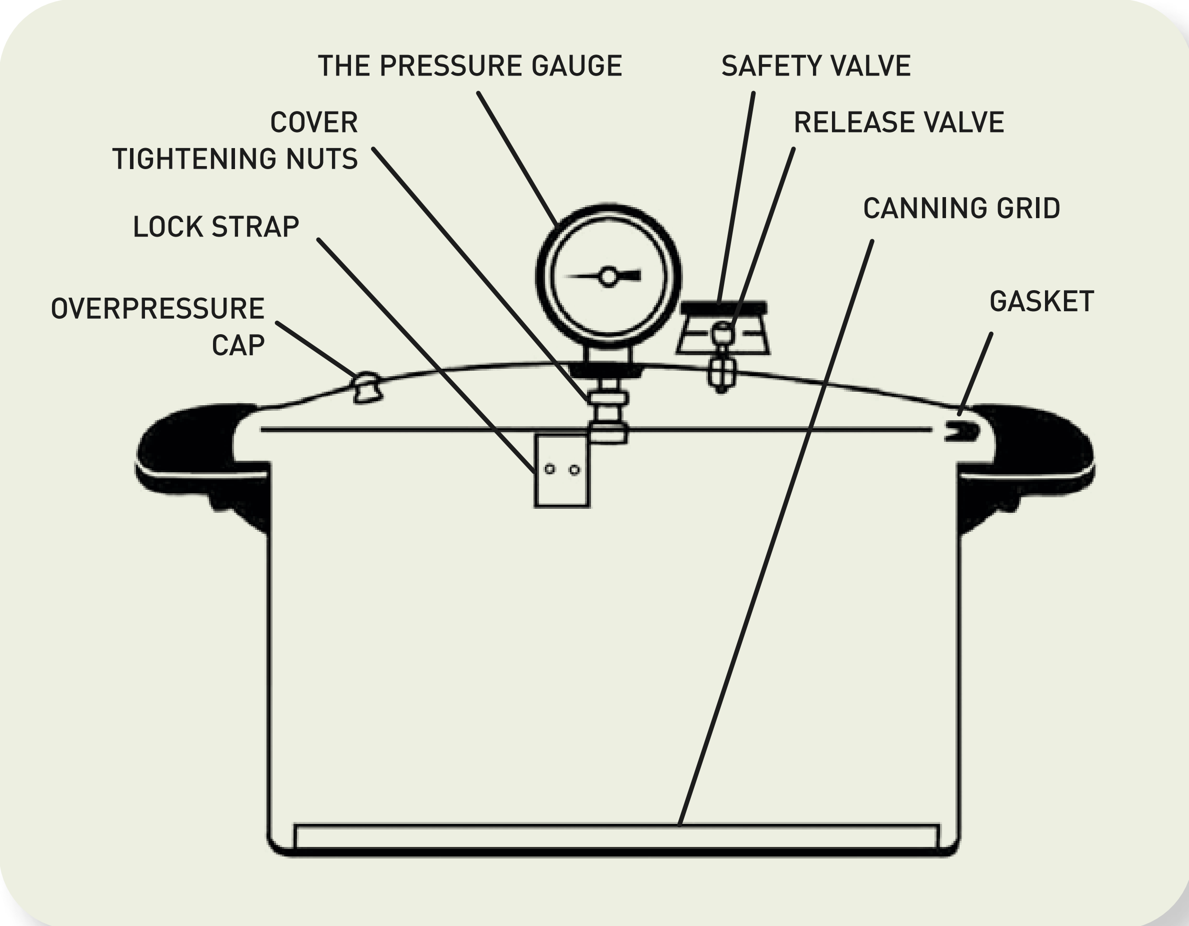


Figure and image of a table-top autoclave

The following instructions generally apply when sterilising foods:

- Place a rack on the bottom of the pan to ensure that the jars/bottles/tins are not too close to the heat source.
- Do not plunge the filled glass jars or bottles directly into boiling water, as they will most likely crack. Heat the water in the pan up to approximately the same temperature as the filled jars or bottles, before submerging them in the water.
- Do not screw the lids on too tightly, so that some air is able to escape
- Do not pack the jars or bottles too tightly in the pan. Leave some space between them and check that they do not touch the sides of the pan.
- Cover the jars or bottles with at least 5 cm of water.
- The sterilisation time begins from the moment the water reaches the desired temperature.
- For optimal results use jars of the same size and volume.
- Never try to open the autoclave or pressure cooker while the water is boiling. The high pressure in the pan and the high temperature of the water make this very dangerous!

Remember the following points when sterilising under high pressure using tins or glass.

- **Tins**: after sterilisation, let the steam escape slowly from the pan. This happens quicker for small tins than with bigger ones, but still should be done slowly and carefully, as the tins can deform or even burst. Wait until the pressure returns to normal before opening the lid of the pressure cooker/autoclave. Remove the tins and immerse them in cold water, which should be refreshed occasionally to keep it cold. When the tins are cool, dry them.
- **Glass jars**: wait until the pressure cooker has cooled and the inside pressure has gone down before opening the lid. Remove the jars and tighten the lids immediately. The disadvantage of glass jars is that they cannot be cooled quickly. The safest way to cool them is to keep them in the open air until they are lukewarm, before plunging them into cold water.

The advantage of using an autoclave over a pressure cookers, is that it cools down faster. On the other hand, an autoclave requires more water and therefore more energy to heat.

4.3.3. Storage and consumption

Always store canned food in a cool place, preferably at a temperature below 20°C. Keep glass bottles and jars in a dark place. Label the containers so that you know what they contain and the date they were preserved. Always consume the older products first. The storage area must be dry and the temperature kept constant.

Moisture will make tins go rusty. Examine the containers well before opening. A bulging lid or deformed tin indicate that gas bubbles have been formed by bacteria (*Clostridium*) and that the food is spoiled. Examine the food carefully and smell it. Heat the food if necessary and never eat anything you suspect may be spoilt.

Bulging lids due to the formation of gas (botulism)

Remember that preserving fruit and vegetables is always a risky undertaking. Always follow the rules described in this manual and keep in mind that the heating times given in the appendices represent the minimum time required. Never heat products for a shorter time than recommended. Heating food for a longer time reduces the chance of spoilage, but it also affects the food's taste and reduces the nutritional value.

4.4. PRESERVING BY COOLING

4.4.1. Benefits of cold preservation and temperature limits

Cooling is a food preservation technique which stops or slows down cell activity, enzymatic reactions and the growth of micro-organisms. It also prolongs the shelf life of fresh, vegetable and animal products by limiting its spoilage. However, **cooling does not destroy toxins or micro-organisms which may be present within the food**. Most micro-organisms can therefore resume their activity as soon as they return to a more favourable temperature.

Fruit and vegetable respiration **releases energy** in the form of heat. The quantity or respiratory intensity of this energy varies depending on the product type, the variety, its ripeness, the extent of injuries and product temperature. Furthermore, most products deteriorate quickly if the **field heat** is not eliminated before they are loaded for transport.

It is **the temperature of the fruit and vegetables has the most impact on respiratory activity.** Prompt, quick and uniform cooling upon harvest, *i.e.* elimination of field heat, is crucial to reduce respiratory intensity. Cooling slows the spoilage process and gives the product a longer shelf life. The rule of thumb is that, for every hour that cooling is delayed, the product's shelf life is reduced by one day. This rule does not apply to all crops, but mainly to highly perishable crops harvested in high heat.

Lowering the temperature of the fruit or vegetable also reduces the rate of ethylene production, dehydration, the multiplication of micro-organisms and spoilage from injuries.

Longer shelf life for fruit and vegetables is basically associated with the temperature levels within which they can be stored satisfactorily.

- The **lowest temperature limit** possible is the product freezing point (not always 0°C), below which the plant cells are destroyed (and enzymes released). Since most products are vulnerable to damage caused by refrigeration, care should be taken **not to pre-cool or to store products below the recommended temperature.** Often the effects of such accidents do not appear until the retail sale stage. These include the failure to ripen normally, rot, shrivelling and discolouration of fruit and vegetables.
- The **upper limit** is less well defined and corresponds to each product's specific sensitivity to the increase in temperature, relative to the shelf life target.

4.4.2. The two methods of preserving by cooling

There are two methods that use cooling: refrigeration and freezing (which will be discussed in more detail in the next chapter).

- **Refrigeration:** this involves storing the food at a **low temperature**, **close to, but higher than the point of freezing.** Generally the refrigeration temperature is around **0°C to +4°C.** At these temperatures, the growth rate of micro-organisms in food is slowed. Refrigeration therefore allows perishable food to be preserved in the short or medium term. Some basic rules must be followed when cooling food. Refrigeration must take place as soon as possible after picking and applies to all initially healthy food, and must be continued throughout the distribution chain.
- **Freezing:** this maintains the temperature at the core of the product at **a low of -18 °C.** This process causes the water within the food to crystallise into ice. There is then a significant reduction in the available water, *i.e.* a drop in water activity (WA), which slows down or stops microbial and enzymatic activity. Freezing therefore allows food to be preserved for longer than refrigeration. Depending on the cooling speed, two different methods are used.
    - **Fast or flash freezing**, during which the food is stabilised by a sudden reduction in temperature to -18 °C at the core. This technique allows several small ice crystals to form which do not decompose the food. Only a small amount of exudate is produced during thawing.
    - **Slow freezing**, which applies to products not suitable for freezing at the higher speed, to which quick-frozen products are subjected. In this case, however, the food is cooled slowly and relatively large ice crystals form compared with the size of the product's cells. The sharp needle-like ice crystals can tear the walls of weak cells and promote some exudation during thawing.

4.4.3. Why pre-cool products?

In a cold chamber, products are stored in cold facilities and **cool slowly but not uniformly**, mainly under the effect of conduction and also by natural convective contact with the cooled air. Most products deteriorate quickly if field heat is not eliminated rapidly. In most cold chambers, the **temperature rises every time a new lot of** warm fruit and vegetables is added. If this rise is significant due to insufficient capacity of the refrigerating unit, the other fruit and vegetables stored in the chamber become warmer and transpire.

Pre-cooling to remove heat aims to bring the product to the recommended storage temperature and relative humidity as quickly as possible.

Pre-cooling should take place **as soon as possible** after the products are harvested and transported to the packing station. This operation is crucial to maintain the quality of fruit and vegetables.

Pre-cooling extends the product's shelf life by reducing:

- field heat;
- respiration rate (heat released by the product);
- ripening speed;
- loss of humidity (the product shrivels and wilts);
- production of ethylene (maturation gas emitted by the product);
- the spread of decomposition.

Important considerations

1. To reduce "field heat" as far as possible, and consequently the demand for cold which will need to be met by the pre-cooling equipment, harvesting should take place early in the morning. Harvested products should be protected from the sun until they can be placed in refrigerated facilities.
2. Refrigerating equipment is designed to **maintain the desired temperature** and should not be used to remove field heat from products packaged for shipping. Furthermore, **without a dehumidifier relative humidity cannot be raised or controlled by refrigerating equipment**.

Pre-cooling requires the use of a "pre-cooling tunnel", but in the absence of such equipment, part of the cold chamber can be fitted out for this purpose.

- **The pre-cooling tunnel**
  - Forced-air cooling is one of the methods used to extract field heat from freshly harvested products. It can be used for most fruit and vegetables. This method involves the use of **powerful fans** that suck up the refrigerated air and force it though the stacks of products to be cooled. Rapid and uniform convective-type cooling results from active circulation of the cooled air, at high speed around the warm fruit and vegetables. This process results in quick cooling to very low temperatures.
  - The facility must be equipped with **strong cooling capacity** and allow intense ventilation.
  - It is better if the air is **sucked rather than blown** through the products because it is easier to prevent the cooled air from "short circuiting" as much as possible, *i.e.* preventing it from flowing directly to the fan without going through the stored products. Air will not flow as evenly if blown as it will if sucked through the products. With proper container design and orientation, products can be cooled quickly and evenly, whether they are contained in baskets, crates, bins or sacks.

- A forced-air cooling tunnel uses cooled air much more efficiently than a cold chamber. Despite the additional cost involved, it is best to fit out a cold chamber reserved for forced-air cooling and to transport the cooled products to refrigerated premises where they can be stored over a longer period.
- **With this method, however, it is hard to avoid a significant loss in product weight.**

Pre-cooling oranges and clementines in a pre-cooling tunnel, packaged in crates, labelled and placed on disinfected pallets, before being moved to the cold storage room where they will remain until being shipped.

- **Fitting out a section of the cold chamber**
  - A compromise is to **set up a forced-air cooling area by** partitioning a corner of the cold chamber using a **tarpaulin suspended from the ceiling**. This is a modification that involves guiding the ambient air through the stacks of products by covering them with a removable tarpaulin. This method helps to reduce temperature fluctuation, but it should only be used as a stopgap measure.
  - The pallets are placed in such a way as to provide a central air recovery channel to imitate the effect of a pre-cooling tunnel.
  - This mobile system makes it possible to use cold chambers for rapid cooling.

More information can be found in one of the appendices to this chapter on forced air cooling speeds rate and the factors that influence this operation.

4.4.4. Role of packaging in the cold chain

Packaging also has an impact on product shelf life. It fulfils a large number of functions for fruit and vegetables, especially once they reach the consumer. In addition to protecting against shocks and ensuring market appeal, packaging **is an unavoidable constraint for preservation but can also be a cause for improvement.**

Between harvest and packing, products are generally placed in temporary containers such as crates, cardboard boxes and so on. In practice, **the size of these containers should be limited to take account of the release of respiratory heat**. A maximum difference of 0.5°C between the different parts of these containers (such as the bottom and the walls) is tolerable.

During distribution, packaging **plays an important role in the cold chain**. It acts as a division between lots and serves as a barrier to heat exchange, warming and cooling.

It is therefore important to provide the most stable temperature possible during transport. Changes of temperature can cause serious damage to products through **condensation** that occurs on cold packaging walls. If fruit and vegetables become wet, they are easily attacked at these temperatures by mould and bacteria, especially in small packaging units, trays, plastic pouches, etc.

4.4.5. The role of transport in the cold chain

Many products are shipped in non-refrigerated containers or on pallets for air freight. This requires good coordination with departure and destination airports to protect the products, particularly when flights are delayed.

Airports must have temperature-controlled storage installations to ensure product quality. Refrigerator containers exist and should be used as often as possible. Tarpaulin can also be used to provide thermal insulation.

The **design of vehicles** for the transport of plant products must take account of the same constraints as those for premises. In practice, short-distance transport rarely has specific means available. At best, it provides a temperature close to that of loading temperature, which is usually sufficient.

The issue is more complex for longer transportation because equipment is rarely used for just one purpose and the operating scheme must be adapted case by case depending on the requirements of the lot being transported.

Constraints need to be analysed to ensure the best possible compromise and **surveillance is required during transport**.

4.5. OTHER PRESERVATION TECHNIQUES

4.5.1. Sulphuring

Sulphuring involves adding sulphur. Sulphur, in the form of sulphur dioxide or sulphites, is an antiseptic which inhibits the growth of micro-organisms (e.g. it is used as a fungicide in agriculture). In strong doses it inhibits all forms of fermentation (e.g. in must and wine). In weak doses, it naturally selects the micro-organisms most conducive to fermentation, as it is more active on bacteria than on yeast.

Sulphur dioxide (formula SO_2 or anhydrous sulphur by its real name) is also an antioxidant. It helps prevent oxidation, as it blocks the action of oxidases. Sulphuring is commonly used to preserve wine. This involves adding sulphur dioxide to must or wine for vinification and promotes better preservation. By using sulphur dioxide, the fermentation process can be slowed down or even stopped (if the concentration is high enough).

By using the available oxygen faster than other oxidisable substances, SO_2 prevents the colour matter from browning too much or certain elements of the aroma becoming too intensely oxidised. This is why fruit, such as lychees, is sometimes treated by **burning sulphur** and exposing it to the "smoke" (sulphur dioxide gas) or by dipping it in a sodium sulphite or bisulphite solution to prevent browning. This preservation technique is has the advantage for producers of being available in several forms, such as solutions, powder, effervescent tablets, wicks or burning discs. In Madagascar, sulphur is placed in boxes within a closed container containing crates of freshly harvested lychees. The sulphur pellets are lit (sulphuring) and the smoke is emitted within the container, which remains firmly closed for a while to enable to sulphur to be deposited onto the fruit. This technique is still somewhat random in terms of how evenly the sulphur is distributed.

Sulphites (formula SO_3^{2-}), which are used as preservatives, have antioxidant and antibacterial properties. Sulphuring therefore allows for better preservation of colour, taste and vitamin C, but it can also have some harmful effects, particularly modifying the flavour of the product or giving it a "rotten egg" smell when not performed properly. In addition, the sulphites that remain in the product after sulphuring may be dangerous. In strong concentrations, sulphites are allergens. People who are sensitive to sulphites may experience a reaction similar to that of a food allergy. Sulphites can trigger asthma and symptoms of anaphylactic shock. Many people who are asthmatic may also be sensitive to sulphites. Maximum levels of sulphur (MRLs as residues) or sulphites (as a preservative) have therefore been set by regulation following WHO recommendations on sulphite intake.

4.5.2. Preserving vegetables in salt

Salting is one of the oldest methods of food preservation for vegetables (it is not suitable for fruit), especially in areas where inexpensive salt is easy to come by. Salting has a shorter shelf life than sterilisation, but it can still preserve products for a few months.

As salt absorbs a large quantity of water from food, it is difficult for micro-organisms to survive. Salt has a strong dehydrating capacity. It draws water from the food, dissolves and penetrates into the core of food, thereby preventing the growth of micro-organisms. Some foods preserve better in dry salt, brine or in a very salty water solution. Salt has a tendency to harden the skin of vegetables. Metal should not be used for food preserved using salt.

There are two salting methods The first uses a lot of salt, whereas the second only uses a small amount. The disadvantage of the first method is that it has a very negative impact on the taste of food. To overcome this problem, food can be rinsed or soaked in water before it is eaten, but this decreases its nutritional value. It is therefore advisable to only use this method when there is a surplus of fresh vegetables and no other method is possible.

Using a small amount of salt is not in itself enough to prevent the growth of bacteria, but it does result in the development of a certain kind of acid-producing bacteria that limits the growth of other bacteria. One example of a product made this way is sauerkraut, which has a high nutritional value. (Historically it enabled sailors to remain at sea for many months without suffering from scurvy due the high levels and preservation of vitamin C or ascorbic acid).

This preservation method **requires two ingredients**.

- **Salt:** use fine salt with no anti-agglutinating agent. Desanitise salt that is not pre-packed or that is locally extracted by sprinkling the salt on a metal sheet and heating over a hot fire. The salt used is untreated sea salt which is rich in magnesium and other mineral salts. Coarse salt is generally used to preserve vegetables. It is possible to add herbs to the preparations, such as bay leaves, thyme, peppercorns, cloves, juniper, coriander berries, tarragon, etc.
- **Vinegar**: Use white vinegar with a concentration of 4-5%.

Salting **only requires very simple equipment, but hygiene needs to be impeccable.**

- Jars, cans or other containers: they may be made of wood, plastic, ceramic, glass or stainless steel. Jars must be perfectly clean. They must be washed in a soda bath and rinsed with clean hot water.
- A muslin (very thin permeable fabric) is placed between the vegetables and the plate. It is used to remove froth from the surface of vegetables.
- Pressure plate: this is a plate or grid made of wood, ceramic, glass, stainless steel or plastic. A weight is placed on top of this to keep the vegetables submerged. The pressure plate should be slightly smaller than the diameter of the container. A pressure plate that catches under the neck can be used with certain jars, in which case a weight is not needed.
- Weight: this is put on the pressure plate to keep the vegetables under the surface of the liquid. The weight can be a clean stone or a glass jar filled with water.
- Scales and/or a measuring cup: these are needed to weigh or measure the right amount of vegetables, salt and vinegar.
- Knives: stainless steel knives are needed to chop the vegetables.

4.5.2.1. Heavy salting (20-25 %)

Heavy salting is a simple preservation method, and much less labour intensive than preserving with a small amount of salt.

It involves using 1 part salt to 5 parts vegetables (e.g. 250 g salt per kg of vegetables). Vegetables will therefore taste very salty and will need to be soaked in water for some time before eating.

Vegetables and salt are mixed in large pots. Salt is added in the form of dried grains or brine (salty water solution in a variety of concentrations). Sometimes a little vinegar can be added. The pots are filled with the vegetable/salt mixture and then covered with a muslin cloth and a pressure plate, on which a weight is placed to ensure that it is fully sealed. Finally the brine (250 g salt per litre of water) is added until the product is completely covered. Check that the vegetables remain fully submerged in the liquid.

After about two weeks, the salted product can be decanted into smaller jars about the size of one portion. Contamination can occur quickly once the jar has been opened. The remaining liquid from the pots is poured over the salted product in the smaller jars, until the vegetables are completely covered. The jars are sealed tightly and then stored them at as cool a temperature as possible.

Before using, the vegetables normally have to be soaked in fresh water for half a day (1 kg vegetables in 10 litres of water). However, the vegetables lose nutrients during soaking, and this should therefore be avoided where possible, for example, when the vegetables are to be used in soup. As a point of safety, the prepared vegetables should be cooked before use. Peas, beans, sweetcorn and green vegetables preserved in salt need cooking for at least 10 minutes before eating.

4.5.2.2. Using heavy bring (20%)

The pots or jars are filled with the preprepared vegetables. The brine (200 g salt + 65 ml vinegar per litre of water) is poured onto the vegetables until the pressure plate is just submerged. The required quantity of brine is about half of the volume of the vegetables. To maintain the proper salt concentration, 200 g of salt per kg of vegetables is sprinkled over the pressure plate. The pots are kept at 21-25°C and the vegetables are checked to ensure they remain under the brine. Brine (200 g salt + 65 ml vinegar per litre water) should be added when necessary.

The vegetables have to be packed into smaller jars after about two weeks. The old brine is used, possibly with the addition of fresh brine so that the vegetables in the jars are submerged. The jars are then tightly sealed. Before use, the vegetables usually need soaking in fresh water for half a day (10 litres of water for every kg of vegetables).

4.5.2.3. Using small amounts of salt

Just enough salt is added to the vegetables to create the appropriate conditions for the growth of micro-organisms which form acids, which will in turn preserve the vegetables. Acid gives products a distinct taste that is popular. Add 1 part salt to 20 parts of vegetables as dry salt or as light brine. When vinegar is also added to light brine less salt is needed. The brine method is easier than the dry salt method, as brine gives an even distribution of salt and vegetables, which is a vital for this method to succeed. With the dry salt method, the product will shrink when it is no longer immersed in liquid. However, the colour, odour and taste are better when preserved with salt than with brine.

The preparation for salted or pickled vegetables is the same as for fresh vegetables, although longer cooking times are sometimes necessary.

4.5.2.4. Light salting (2.5-5%)

Sauerkraut

One product made using this method is sauerkraut. After preparing the vegetables (e.g. green beans), mix with some salt (25g salt per kg of vegetables for green beans, 50 g salt + 50 ml vinegar per kg). Fill the pots with the vegetable and salt mixture, packing tightly. Cover the vegetables with several layers of muslin cloth then add the pressure plate and the weight. The salt draws the liquid from the vegetables, which should gradually become covered in brine. If this does not happen within a few hours, add light brine (25g salt per litre of water). Brine for green beans should be made from 50 g salt plus 50 ml vinegar per litre of water. Store the crocks at 20-25°C. The vegetables will undergo an acid fermentation lasting 2-3 weeks. Skim the froth regularly from the surface of the vegetables. A white layer of froth will appear on the vegetables after a few days when fermenting with light brine and light salting methods. This is caused by the growth of undesirable micro-organisms. If this froth is left undisturbed it will use up the acid from the fermentation process and risks making the vegetables smell and taste unpleasant.

The froth is best removed by first removing the weight and pressure plate, and carefully lifting the muslin cloth, keeping the froth on the cloth. Rinse the cloth, together with the pressure plate and weight, and put them back in place. This should be carried out every other day, especially when a large amount of froth is produced.

If the vegetables are to be kept longer than 2-3 weeks, they have to be repacked into smaller containers after fermentation. Vegetables fermented in small jars do not need repacking. The fermented product is packed tightly into glass jars of 0.5-1 litre with a screw cap. Pour brine over the product until it is covered, using the old brine plus fresh brine, where necessary, made from 25 g salt plus 50 ml vinegar per litre of water.

Close the jars, but make sure that air can escape by screwing the lid tight, then giving it a quarter turn back (for the turn and lift caps, unscrew by less than a quarter turn). Heat the jars in a boiling water bath for 25 minutes (for 0.5 litre jars) or 30 minutes (for 1 litre jars). The jars should be tightly closed immediately afterwards. This process will pasteurise the contents and stop fermentation.

4.5.2.5. Light brine (5%)

Fill the jars or pots with the preprepared vegetables, then cover with the muslin cloth, the pressure plate and the weight. Add the brine (50 g salt + 50 ml vinegar per litre water, until the plate is just covered). About half of the vegetables will be in the brine. Keep the jars or pots in a cool place (+/-15°C). An acid fermentation will take place during the next 2-3 weeks. Remove the froth regularly (as described above). After fermentation, it is best to repack the vegetables into smaller jars with screw lids. Pack the glass jars tightly and add the brine until the vegetables are submerged. Where necessary fresh brine can be added using 50 g salt + 50 ml vinegar per litre of water.

Close the jars so that air can escape by closing the twist lid and giving it a quarter turn back. Pasteurise the contents by heating the jars in boiling water (25 minutes for 0.5 litre jars and 30 minutes for 1 litre jars). The jars should be tightly closed immediately afterwards. The vegetables need only be drained and rinsed before eating.

4.5.3. Preserving in vinegar

Some food can simply be preserved in **vinegar,** which contains **acetic acid** (CH_3-CO-OH). Acetic acidis the oldest known preservative. Occurring naturally in humans and plants, it is synthesised in industry and has many uses. It is the most common food additive and a potent antiseptic. The Romans called it *acetum*, or vinegar. All civilisations that practised beer or winemaking discovered the natural acid. It is mainly obtained through synthesis, but also exists in its natural state. The best known industrial application of acetic acid is as a **food preservative**. It is what gives vinegar its flavour and smell. The additive helps metabolise food and improves the quality and safety of a product. It is included in the standards authorised by the *Codex Alimentarius*, the international body ensuring food hygiene. It is not very toxic for humans, even in large quantities.

Vegetables in vinegar

Vinegar is not only used to preserve vegetables (cabbage, beetroot, onions, cucumber), **but also fruit** (particularly lemons and olives). Vinegar is an aqueous solution with a low acetic acid content, which is mainly used in human food as a condiment and a preservative. It is possible to make vinegar at home by fermenting fruit juice (sourced from all kinds of sweet local fruit), or even honey, with water and sugar (aerobic acetic bacteria will transform the sugar first into alcohol and then into vinegar upon coming into contact with oxygen in the air).

When ordinary vinegar is used (5% up to 8-10% acetic acid in water), it has to be heated in a closed pan. The utensils should be made of enamel or stainless steel, as the high acid concentration of the vinegar corrodes other materials. The vinegar should have a minimum concentration of 4%. (The pH has to be lower than 3.5; this can be checked with pH papers). White vinegar (5% acetic acid) or pickling vinegar (concentrations vary up to 100% acetic acid) can be used. The percentage of vinegar stated on the label indicates the level of acidity and not the alcohol level.

Before immersing food in vinegar, it should be salted and heated so that it may be stored. The following method is generally used. The prepared fruits or vegetables are steeped in cold heavy brine (200 g of salt per litre of water) for several days, depending upon the size and shape of the product. Next they are put into a boiling salt solution, boiled, and cooled to 70-80°C. At this temperature the product is transferred to jars (herbs and spices can be added, but not brine). The jars are filled to 1.5cm under the rim. The vinegar used must have a final concentration of about 5% after dilution.

Always use clean glass jars. Close the jars as quickly as possible and cool quickly in a cool, airy place. Store the products at as cool a temperature as possible.

4.5.4. Preserving in alcohol

Alcohol is an excellent preservative for fruit and herbs. It preserves the flavour of food and destroys the micro-organisms. Several types of fruit can be preserved in alcohol, including cherries, apricots, blackcurrants, lemons, quince, strawberries, raspberries, currants, blackberries, blueberries, nectarines, plums, sloes, grapes, elderberries, etc. Herbs and spices such as aniseed, tarragon, mint and vanilla also lend themselves well to alcohol preservation. One could even try to preserve some vegetables, such as fennel or celery in alcohol.

Yellow plums in alcohol

There is a range of different alcohols to choose from, including gin, vodka, brandy and more. However, white eau-de-vie remains the best choice, as it is neutral in colour and taste, which allows you to preserve the flavour of the fruit. Regardless of the alcohol used, it must be between 40 and 45%. It is also possible to use a 90% alcohol, half of which is cut with boiled and cooled water.

To prepare fruit in alcohol, use fruit which is in good condition, *i.e.* not too ripe and not too young. Berries can be used as they are. For larger fruit, such as apples, pears and plums, it is better to prick them in different places before preparing them. This allows the alcohol to reach the core of the fruit.

Example of a preparation with brandy (cherries):

1. Sterilise a glass jar by plunging it open into boiling water. Do not forget to sterilise the lid as well. Leave to dry on a clean cloth facing downwards.
2. Wash and dry 1kg cherries. Remove the stalks and stones.
3. Pack them tightly into the dry sterilised jar.
4. Mix 450 g sugar with 750 ml brandy for fruit. Pour the mixture onto the cherries.
5. Close the jar and leave to marinate for 1 month, giving it a mix every now and then. Label.

Jars of fruit in alcohol keep for 1 year in a cool, dark place. Once open, keep in the fridge, tightly closed. If necessary, add more alcohol so the fruit is always covered. Fruit soaked in alcohol lends itself well to a dessert.

4.5.5. Preserving in sugar syrup

Syrup is a thick, viscous liquid made by dissolving a large amount of sugar in water, with or without added fruit or herbal sugar syrup, which is then cooked over a high heat before being filtered and bottled, or used in a more complex preparation. The viscosity of the syrup comes from the many hydrogen bonds between the dissolved sugar molecules, which carry hydroxyl groups, and the water. Different techniques are used for syrups made from cereals, plants, trees (e.g. maple) and fruit. The sugary flavour and colour of these syrups are nuanced (translucent, amber, brown, darker or coloured) depending on their origin and the amount of refining they undergo. Unrefined syrups are richer in minerals and are often coloured.

In large quantities, sugar limits the growth of micro-organisms. It also enhances and preserves the flavour of fruit and vegetables. Many different types of sugar can be used to make the syrups. As a rule of thumb, white granulated sugar, *i.e.* refined sugar, is used. However, some prefer to use more natural sugar, such as brown sugar or sugar cane. There are also alternatives with a lower glycaemic index than ordinary sugar, such as coconut sugar, Xylitol, or even honey.

The recipe will, however, need adapting as each of these sugars have their own unique characteristics:

- their own taste: for example sugar cane has a distinctive flavour which it imparts on preparations;
- sweetness: this is 30 to 50% higher in Xylitol than white sugar or brown sugar when cooked.

In addition, altering the amount of sugar may affect the shelf life. Some preparations last longer if the percentage of sugar is reduced. **To make the environment hostile to micro-organisms, the sugar content must be at least 65% at the end of cooking.**

Fruit syrups or fruit in syrup can be made.

Here is how to make **fruit syrups**.

1. Mix 1 kg sugar with 1kg crushed fruit.
2. Leave to steep in the fridge for 24 hours.
3. Bring to the boil and leave to simmer for 5 minutes.
4. Meanwhile, sterilise a glass bottle. Plunge it open into the boiling water then leave to dry on a clean cloth, facing downwards. Do not forget to sterilise the lid as well.
5. Filter the mixture using a cheesecloth
6. Remove the foam
7. Pour into the bottle and close.

Syrups keep for one year unopened, and for 4 months in the fridge after opening. They can be used in cocktails, but also poured over ice-cream, fruit, rice pudding, panna cotta and much more.

Fruit in syrup can also be made. Cook the fruit in a mixture of sugar and water. The preparation cannot be preserved by sugar alone and will need sterilising. The syrup is used to cover fruit in jars which are closed and then sterilised at 100°C for 20 minutes in a container large enough to house all the preprepared jars.

4.5.6. Preserving in oil

As with sugar solutions and alcohol, oil can also be used to preserve certain vegetables. The most well-known example is dried tomatoes and confit in olive oil.

Dried tomatoes in oil

After washing, the tomatoes a chopped in half lengthways, then again into quarters before being left to dry either in the sun or in an oven (e.g. at 100°C for 3 hours). Pour a little olive oil into the bottom of the jar, up to about 1.5cm from the rim. Salt the dried tomatoes and put into jars. Close and proceed with the heat treatment immediately at 100°C for about 75 minutes.

4.6. USING ADDITIVES FOR PRESERVATION

According to EUFIC,[28] preservatives are repeatedly the subject of public debate and whenever they are discussed, many consumers associate them with "modern" and "dangerous" chemicals found in food products.

However, as we can see from the past, food preservation dates back centuries, when man first used salt (salting) and smoke (smoking) to stop meat and fish spoiling. Despite some reluctance, preservatives are now an indispensable part of the food we eat. This is partly due to the increasing consumer demand for more choice and convenient products which are easy to use, as well as the higher food safety standards which have become standard practice in the food sector.

The main argument for using preservatives **is to improve food safety by eliminating the effect of biological factors.** For the consumer, the greatest risk is leaving food to spoil or it becoming poisonous due to the effect of micro-organisms (e.g. bacteria, yeast, mould) growing inside it. Some of these organisms are able to secrete poisonous substances, known as toxins, which are a risk to human health and can even be life-threatening.

To delay food spoilage by micro-organisms, **antimicrobial substances** are used, which inhibit, delay or prevent the growth and spread of bacteria, yeast and mould. The following feature among those most of interest to the horticultural sector.

- **Sulphur compounds** such as sulphites (E221 to 228) are used to inhibit the growth of bacteria, for example in wine, dried fruit and vegetables preserved in vinegar or brine.
- **Ascorbic acid** (E300) may be used for several reasons, particularly to preserve potato products, cheese and ham.
- **Benzoic acid and calcium, sodium and potassium salts** (E210 to 213) are used as antibacterial and antifungal agents in foods such as **pickled cucumbers**, low-sugar **jams and jellies**, seasonings and condiments.

Nitrates and nitrites (E249 to 252), which are another important group of substances often used as additives in meat-based products to protect against botulism-causing bacteria (*Clostridium botulinum*) and not in vegetable products. The same applies to natamycin (E235).

28 The European Food Information Council (EUFIC) is a non-profit organisation that provides the media, healthcare and nutrition professionals and educators with information on the safety and quality of food, as well as on health and nutrition, based on scientific research, ensuring that this information is understandable to consumers.

Examples of preservatives commonly used within the European Union, particularly to preserve products of plant origin (according to EUFIC)

E Number	Substance/class	Examples of food products of plant origin in which they are used
E200-203	Sorbic acid and sorbates	Dried fruit Fruit purée
E210-213	Benzoic acid and benzoates	Vegetables in vinegar Jams and jellies (with a low sugar content) Candied fruit
E220-228	Sulphur dioxide and sulphites	Dried fruit, preserved fruit Potato-based products Wine

To ensure that preservatives genuinely contribute towards food safety, **they are subject to a safety assessment and authorisation procedure before being placed on the market.**

- At an international level, there is a mixed expert committee on food additives (**JECFA**), which is both a part of the United Nations Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO).
- On a European level, the bodies responsible for the safety assessment, authorisation, control and labelling of preservatives and other additives are the European Food Safety Agency (**EFSA**[29]) the European Commission, the European Parliament and the Council of the European Union. The authorisation and conditions of use for preservatives are governed by directive 95/2/EC[30] of the European Parliament and the Council of 20 February 1995 on food additives other than colours and sweeteners[31].

As with all other types of additives, the safety assessment of preservatives is based on the examination of all available toxicological data, particularly observations made on human and animal models. The maximum quantity of an additive whose toxic effect is not demonstrable is determined by the available data. This is known as the "no observed adverse effect level" (NOAEL), and is used to identify the acceptable daily intake (ADI) for all food additives. **The ADI provides a good safety margin and indicates the amount of food the additive which may be consumed on a daily basis, over a lifetime, without any adverse health effects.**

29 https://www.efsa.europa.eu/en

30 Directive 95/2/EC of the European Parliament and Council of 20 February 1995 on food additives other than colours and sweeteners: EUR-Lex - 31995L0002 - EN - EUR-Lex (europa.eu)

31 General information on food additives (additive labelling rules, consumption, etc.): https://ec.europa.eu/food/safety/food_improvement_agents/additives_en

Public opinion is profoundly concerned by risks of adverse effects of certain food additives, but in-depth studies show that these fears are based on misconceptions and not on identifiable adverse effects. It has rarely been demonstrated that preservatives can **cause allergic** (immunological) **reactions**. Among the food additives for which allergic reactions have been reported, some preservatives from the sulphite group, including several inorganic sulphites (E220 to 228) as well as benzoic acid and its derivatives (E210 to 213), are likely to trigger asthma attacks characterised by difficulty breathing, shortness of breath, wheezing and a cough in sensitive individuals (e.g. asthmatics)

In collaboration with the Council of the European Union, the European Parliament has developed a **detailed labelling system for food additives**, in order to enable consumers to make an informed choice about food containing preservatives. The legislation also states that additives must be mentioned on the packaging of food products by category (preservatives, colours, antioxidants, etc.), either by name or by their European Union code (the letter E followed by a number). In summary, preservatives are still necessary to ensure the safety and diversity of available food products. They delay food spoilage and prevent changes to the flavour and appearance of food. The evaluation of preservatives and their use in food products are strictly controlled, both on a European and an international level.

4.7. APPENDICES

A.1. Temperatures and relative humidity recommended certain horticultural products

Sources cited on the FAO website:

- B.M. McGregor, "Tropical Products Transport Handbook", USDA Office of Transportation, *Agricultural Handbook*, no. 668, 1989.
- A.A. Kader, "Postharvest Handling", in J.E. Preece et P.E. Rend, *The Biology of Horticulture – An Introductory Textbook*, New York, John Wiley & Sons, 1993, pp. 353-377

Product	Temperature (°C)	RH (%)	Approximate shelf life
apricots	0	90-95	1-3 weeks
garlic	0	65-70	6-7 months
pineapples	7-13	85-90	2-4 weeks
artichokes (whole)	0	95-100	2-3 weeks
asparagus	0-2	95-100	2-3 weeks
aubergines	12	90-95	1 week
avocados	4.5-13	85-90	2-8 weeks
bananas (green)	13-14	90-95	1-4 weeks
Swiss chard	0	95-100	10-14 days
sweet potato	13-14	85-90	4-5 months
broccoli	0	95-100	10-14 days
cantaloupe melon (3/4)	2-5	95	15 days
cantaloupe melon (whole)	0-2	95	5-14 days
star fruit	9-10	85-90	3-4 weeks
carrots (with tops)	0	95-100	2 weeks
carrots (ripe)	0	98-100	7-9 months
carrots (before ripe)	0	98-100	4-6 weeks
celery	0	98-100	2-3 months
celeriac	0	97-99	6-8 months
sour cherries	0	90-95	3-7 days
sweet cherries	-1	90-95	2-3 weeks
mushrooms	0	95	3-4 days
cabbages (underripe)	0	98-100	3-6 weeks
cabbages (late)	0	98-100	5-6 weeks
cauliflower	0	95-98	3-4 weeks

lemons	10-13	85-90	1-6 months
gourds	10-13	50-70	2-3 months
clementines	4	90-95	2-4 weeks
cucumbers	10-13	95	10-14 days
dasheen/taro	7-10	85-90	4-5 months
dates	0	75	6-12 months
endives	2-3	95-98	2-4 weeks
spinach	0	95-100	10-14 days
fresh figs	0	85-90	7-10 days
strawberries	0	90-95	5-7 days
tuberous peas	10	90	4 weeks
ginger	13	65	6 months
pomegranates	5	90-95	2-3 months
green beans	4-7	95	7-10 days
yams	16	70-80	6-7 months
jicama	13-16	65-70	1-2 months
lettuces	0	95-100	2-3 weeks
leaf green vegetables	0	95-100	10-14 days
limes	9-10	85-90	6-8 weeks
lychee	1.5	90-95	3-5 weeks
sweet corn	0	95-98	5-8 days
mandarins	4	90-95	2-4 weeks
mangos	13	85-90	2-3 weeks
cassava	0-5	85-90	1-2 months
melons (Casaba, Crenshaw, Honeydew, Persian)	7	90-95	2-3 weeks
turnips	0	95	4-5 months
nectarines	0	90-95	2-4 weeks
coconut	0-1.5	80-85	1-2 months
fresh olives	5-10	85-90	4-6 weeks
dry onions	0	65-70	1-8 months
spring onions	0	95-100	3-4 weeks
blood oranges	4-7	90-95	3-8 weeks
oranges (CA, AZ)	3-9	85-90	3-8 weeks
oranges (TX, FL)	0	85-90	8-12 weeks
Jaffa oranges	8-10	85-90	8-12 weeks

grapefruits	15	85-90	6-8 weeks
papayas	7	85-90	1-3 weeks
watermelon	10-15	90	2-3 weeks
summer squashes	5-10	95	1-2 weeks
sweet potatoes	13-15	85-90	4-7 months
parsley	0	95-100	2 months
peaches	0	90-95	2-4 weeks
cucumbers	4	85-90	1 month
dried chillies	10	60-70	6 months
leeks	0	95-100	2-3 months
pears	-1.5-0.5	90-95	2-7 months
peppers	7-13	90-95	2-3 weeks
apples	-1-4	90-95	1-12 months
new potatoes	15	90-95	10-14 days
late cropping potatoes	13	90-95	5-10 months
pumpkins	10	50-70	2-3 months
plums/prunes	0	90-95	2-5 weeks
radish/daikon	0	95-100	1-4 months
horseradish	-1-0	98-100	10-12 months
grapes, wine	-1	90-95	1-6 months
rhubarb	0	95-100	2-4 weeks
ripe-green tomatoes	8-22	90-95	1-3 weeks
ripe-firm tomatoes	3-15	90-95	4-7 days

A.2. Compatibility groups for storing fruit and vegetables

Source cites on the FAO website:

B.M. McGregor, "Tropical Products Transport Handbook",
USDA Office of Transportation, *Agricultural Handbook*, no. 668, 1989.

Group 1: Low temperature (0 to 2°C), high RH (90-95%), may produce ethylene	
apricots cherries mushrooms figs (not with apples) strawberries raspberries pomegranates persimmons lychees turnips nectarines	coconuts oranges (Florida, Texas) peaches apples leeks pears plums radishes horseradish grapes (without sulphur dioxide)

Group 2: Low temperature (0 to 2°C), high RH (90-95%), may be sensitive to ethylene	
artichokes asparagus bok choy broccoli carrots mushrooms celery cauliflower mushrooms endives spinach kiwis	lettuce leafy vegetables sweet corn turnips (without leaves) parsley peas leeks (not with figs or grapes) spring onions (not with figs, grapes, rhubarb or corn) radishes rhubarb

Group 3: Low temperature (0 to 2°C), lower RH (65-70%), humidity damages these products
garlic dry onions

Group 4: 5°C, RH 90-95%	
cantaloup melons lemons clementines lychees mandarins	cassava oranges (California, Arizona) pepino tangelos

Group 5: 10°C, 85-90%, sensitive to cold and can be sensitive to ethylene	
aubergine	olives
cucumber	paprika
summer squash	chillies
okra	peppers
beans	potatoes for storage
green beans	taro/dasheen
kiwano	
malanga	

Group 6: 13-15°C, 85-90% RH, sensitive to cold, can produce ethylene	
pineapples	mangosteen
avocados	mangos
bananas	melons
boniato	grapefruits
star fruit	papayas
winter squashes	plantains
feijoa	new potatoes
ginger	ripe tomatoes
limes	

Group 7: 18-21°C, 85-90% RH, sensitive to cold, produce ethylene
Ripe green tomatoes
pears (for ripening)

Group 8: 18-21°C, 85-90% RH, sensitive to cold, sensitive to ethylene
yams
jicama
watermelon
sweet potatoes

A.3. Product cooling times

Source: H.W. Fraser, "Tunnel Forced-Air Coolers for Fresh Fruits and Vegetables", Fact sheet, Minister of Agriculture, Food and Rural Affairs, Ontario, 1998, www.omafra.gov.on.ca/french/engineer/facts/98-032.htm.

All fruit and vegetables cool quickly at first, then more slowly. The rate of cooling by forced air depends on several factors:

- the density of products inside the containers (the less tightly packed they are, the faster they cool);
- the type of container, orientation and venting characteristics (if the air enters passes uniformly and evenly around the produce, cooling will be quicker);
- the volume to surface area ratio of the product. The lower the ratio, the quicker it will cool (cherries will cool faster than melons);
- the distance travelled by the cooled air (the shorter the distance, the faster the whole pile will cool);
- the airflow capacity (the higher the airflow the faster the cooling).

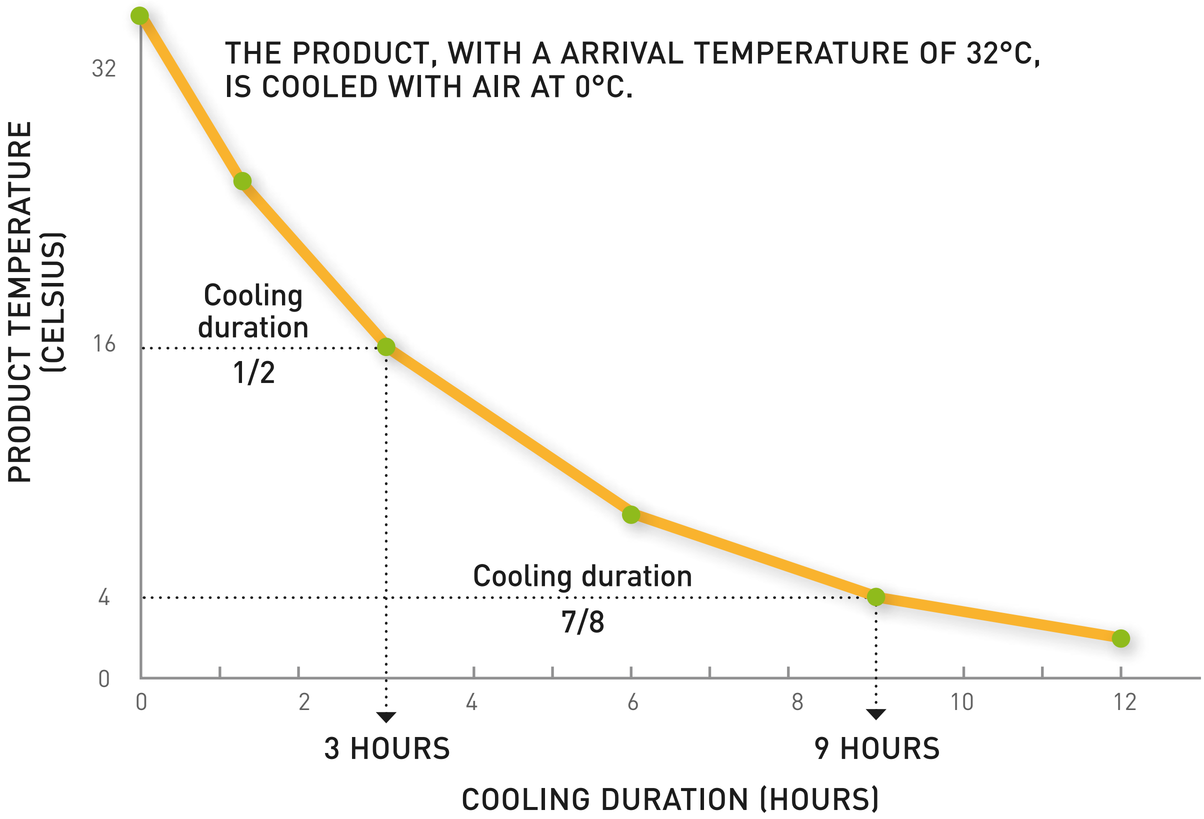
The relative humidity of the cooled air has little impact on moisture loss as long as it is above 85% and the cooling period is less than one or two hours.

Regardless of the temperature of the cooling air or that of the incoming produce, the cooling curve remains the same provided that all the other factors listed above are kept constant. Only the cooling speed changes.

The expression "7/8 cooling time" is a standard industry term that describes the time needed to remove seven-eighths (87.5%) of the temperature difference between the starting produce temperature and the temperature of the cooling medium (refrigerated air, in the case of forced-air cooling).

This is a convenient method for indicating when produce has come as close as possible in practical terms to the temperature of the cooling medium.

The 7/8 cooling time is measured from the moment the produce is first placed inside the tunnel. For example, with the air at 0°C, if it takes nine hours to lower the temperature of a peach from 32°C on its arrival to 4°C, 7/8 cooling time is nine hours. In other words, the temperature difference between the produce and the cooling air, which was 32°C, has been reduced by 28°C. The 7/8 cooling time is theoretically three times as long as the 1/2 cooling time. As a result, the same peach that took 9 hours to cool to 4°C, would only take 3 hours to cool to 16°C, the temperature at 1/2 cooling time, all other factors remaining equal. In practice, 7/8 cooling time does not often correspond to three time the 1/2 cooling time because conditions rarely remain exactly the same over the forced-air cooling period.



Curve showing the typical temperature of products depending on the cooling time

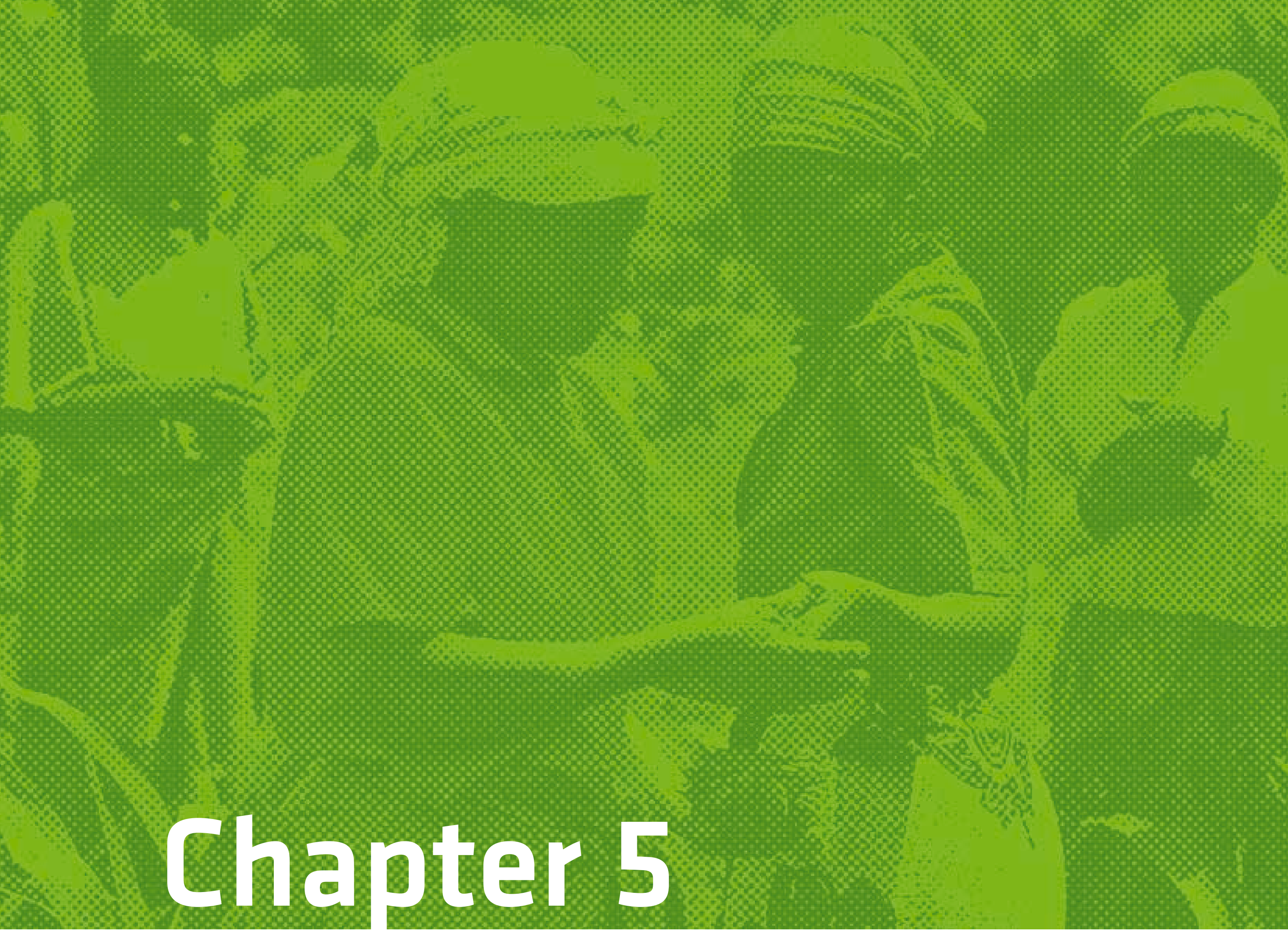
Sometimes the time a product will take to reach 7/8 cooling can be estimated if other cooling times are known. The table below lists cooling time relationships.

Factors used to calculate the 7/8 cooling time	
If you know this cooling time...	...multiply by the following to estimate 7/8 cooling time
1/4 cooling time	7.5
3/8 cooling time	4.5
1/2 cooling time	3.0
3/4 cooling time	1.5

For some crops, it might not be necessary to operate the forced-air cooler at temperatures as low as the optimum holding temperature. For example, some fruit and vegetables can be cooled with forced-air to 5°C, then placed in a cold chamber where they will finish cooling more slowly. This compromise eliminates the need for a refrigeration defrosting system in the forced-air cooling chamber.

Most fruit and vegetables can be cooled by forced-air, but the 7/8 cooling time should be shorter for some products with the following characteristics:

- high respiration rates at harvest;
- lose moisture easily (berries /leafy vegetables);
- very ripe, e.g. tree-ripened peaches;
- to be transported a long distance.



Chapter 5

Preparation of fruit juices and fruit nectars

5.1. DEFINITION AND GENERAL PRINCIPLES

5.1.1. What is meant by fruit juice?

Fruit juice is defined by the *Codex Alimentarius* as "the unfermented but fermentable liquid obtained from the edible part of sound, appropriately mature and fresh fruit or of fruit maintained in sound condition by suitable means including post harvest surface treatments".

This definition therefore begins with the important notion of an "unfermented but fermentable liquid". Fermentation is a phenomenon resulting from the action of micro-organisms and causing the transformation of molecules (usually sugars) into other molecules (acids, alcohols, etc.). Fermentation is a:

- positive phenomenon, if it is controlled and accompanied by the development of molecules of interest (for preservation or taste);
- negative phenomenon, in a situation where the fermentation is **uncontrolled or unwanted**, because the molecules produced by the fermentation can bring **undesirable tastes** to the product.

  In addition, if the growth of micro-organisms takes place in an uncontrolled manner, **spoilage flora**, or even pathogenic flora, can develop and therefore induce a negative change in the organoleptic qualities of the product.

  In the event that pathogenic flora develops, the product can also become a genuine risk vector for consumers.

The most important thing to remember is that if nothing stops the phenomenon, **fermentation will inevitably take place**. The basic concern of any fruit (or vegetable) juice producer will therefore be to avoid this spontaneous fermentation of the juice.

5.1.2. How is fermentation prevented?

The micro-organisms, **mainly yeast**, naturally present on fruits, can be responsible for the spontaneous fermentation phenomenon which, in the case of fruit juices, is uncontrolled and unwanted. It should also be noted that **high temperature conditions** favour and accelerate spontaneous fermentation; this phenomenon is therefore all the more likely to occur in tropical areas.

To prevent the flora naturally present on the fruits from inducing this phenomenon, it is necessary to be able to impede this activity, specifically by destroying it (e.g. sterilisation) or by removing it (e.g. microfiltration). **In preventing any possible action by the flora, fruit juices therefore remain unfermented products.** However as the sugars are still present, these products remain fermentable, and, under the right conditions, the phenomenon can reoccur - hence the importance of the preservation processes described below.

In order to prevent spontaneous fermentation, various processes can be used.

5.1.2.1. Thermal processes

Thermal processes are among the most common preservation processes used to prepare fruit juices. The general principle is to submit the product to a heat source in order to destroy all or part of the microflora present.

In summary, the two main types of heat treatment used are **pasteurisation and sterilisation.** These two treatments are based on different time-temperature pairs.

The thermal process most commonly used in the production of fruit juice is **pasteurisation**, which is **less aggressive for the product**, **because the temperatures used are lower** than those during sterilisation. The pasteurisation process does ensure that all pathogenic micro-organisms are eliminated, however this does **not include all** micro-organisms. It is important to remember, however, that the pasteurisation of fruit juice is preferred over sterilisation, as exposing the juice to very high temperatures for a longer period of time can cause visual or taste defects.

On the other hand, **during the sterilisation process all micro-organisms** are destroyed. This explains why pasteurised products have shorter use-by dates than sterilised products.

These heat treatments are advantageous in that they also allow for **the destruction of enzymes.** Enzymes are proteins naturally present in every living thing. Certain enzymes can have **a degrading effect** on certain molecules present in the product. If the enzymes are left intact in the juice, the phenomenon of enzymatic degradation may occur. This is known as the **organoleptic deterioration** of the product and is due to the activity of enzymes present on product components. Since these enzymes are non-thermostable, they can be destroyed by heat treatments.

5.1.2.2. Non-thermal processes

However, in an effort to avoid any spoilage of the product from heat-based processes, new preservation methods have been developed. These processes reduce microbial activity in products without involving heating. These processes, such as **microfiltration**, are increasingly used in the production of fruit juice. The microfiltration process consists of passing the liquid (in this case, the fruit juice) over a membrane impermeable to micro-organisms. The pores of this membrane have a diameter of between 0.1 and 10 µm, thereby enabling it to retain a large proportion of the micro-organisms. The main disadvantage of this method, however, also lies in the size of the pores, because the particulates in the fruit juice (pulp, etc.) can **clog the membrane**.

For information, there are other less common preservation methods, which are increasingly used in the manufacture of fruit juice, such as **pascalisation** (use of very high pressures) or **ohmic treatment** (passing an electrical current through the product).

However, non-thermal treatments **do not allow for the destruction of enzymes** and therefore will not suppress the enzymatic degradation.

5.1.3. Other important points

Beyond preventing the uncontrolled development of micro-organisms, one of the most important levers to play on the organoleptic quality of products remains **the quality of raw materials**. Fruits that have reached **full maturity** will contain more juice, sugar and aromas, which positively impact the quality of the products. On the contrary, damaged fruits with traces of putrefaction will **lead to undesirable tastes** which will alter the quality of the product.

It is also important to work with healthy fruits for health reasons. Indeed, the presence of mould can cause certain mycotoxins to appear and have a negative effect on the health of the consumer. This is why it is important to sort the raw material so that only high quality fruits are left, as is also underlined in the definition of the *Codex Alimentarius*.

5.2. TYPES OF PRODUCTS

The different types of fruit juice have been regulated[32]. The fruit juice market groups together **three main product categories**: pure fruit juices, fruit juices made from concentrated juice and fruit nectars. All are made from fruit juice, but are distinguished by their fruit content and production method. In recent years, a new commercial category of fruit juice has appeared on the market: smoothies, which are notably "smooth" or "creamy" in nature. Products that contain only fruit juices and purées are legally considered to be fruit juices.

First of all, fruit juices can be **classified**:

- **depending on the number of fruits** they contain: therefore, we will speak of a "single fruit juice" in the case where only one kind of fruit is used, and a "mixed fruit juice" otherwise;
- **depending on the technique used** for the preparation of fruit juices.

In order to recognise them, we must refer to the labelling, which must provide information on the composition, characteristics of the product, storage conditions (refrigerated or at room temperature) and its shelf life.

The differentiation of the types of fruit juices aids their classification and also allows the identification of regulations that apply, depending on their composition. Ingredients, in particular those that sweeten the juice, may be added depending on the type of fruit juice produced. As an example, the table below indicates in which category of fruit juice sweetening ingredients may be used (provided that no acidic ingredients such as lemon or lime juice have been added).

	Fruit juice	Fruit juice from concentrate	Water extracted fruit juice	Fruit nectar
Sugars with less than 2% moisture	✓	✓	✓	✓
Sugar syrups	X	✓	X	✓
Honey or sugars derived from fruits	X	X	X	✓

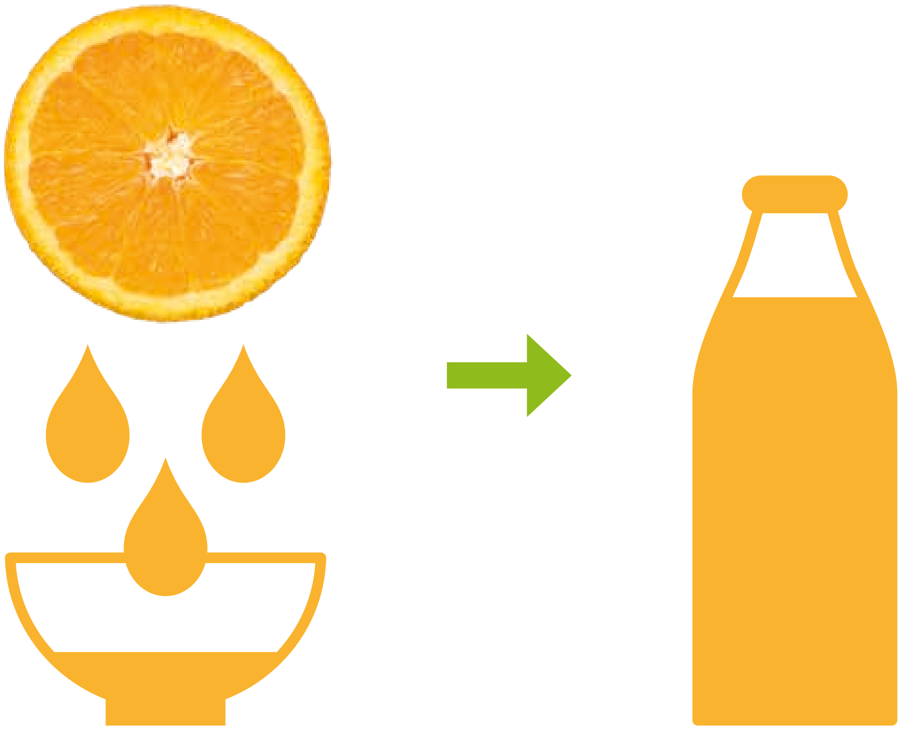
The designations "fruit drink" or "fruit flavoured drink" **are not fruit juices**, and are generally flavoured waters more or less similar to fizzy drinks, containing industrial sugar in large quantities, synthetic syrups or flavourings, and often chemical additives (dyes, preservatives, sweeteners, flavour enhancers, texturing agents, etc.), without the obligation of natural plant extracts.

32 Source of images and definitions: UNIJUS, France.

5.2.1. Fruit juices

These are obtained by directly pressing the fruits using **mechanical processes**. There is never any addition of sugars or additives (colourings, flavours, preservatives, etc.). They can however be clarified by filtering (to remove the pulp) or by enzymatic digestion (enzymes are then added to the juice so that it appears translucent). Conversely, pure juice without clarification is called "cloudy juice". The minimum fruit content is 100%.

In this category, **fresh fruit juice** (without treatment to stop or slow down microbiological activity) can be differentiated from pure fruit juice or 100% pure juice (without the addition of water). Fresh fruit juices that have not undergone any stabilisation treatment can only be stored in the fridge and for a relatively short period of time for the reasons described in the previous section.

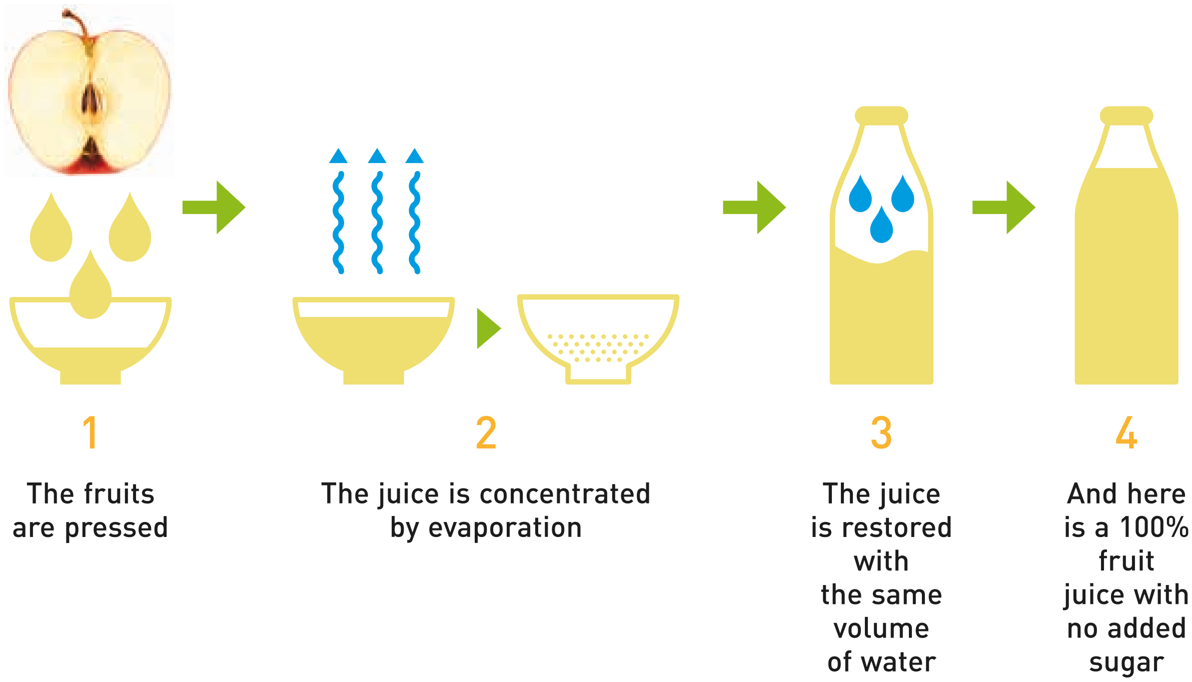


5.2.2. Fruit juice from concentrate

These fruit juices are obtained by **diluting fruit juice concentrate with drinking water**. The fruit juice concentrate is obtained by evaporating the water contained in the juice until it has a Brix level[33] value that is at least 50% higher than the value of the base juice. The minimum fruit content is 100%.

It is especially useful for fruit juices from concentrate for purposes of storage and transport. Effectively, with less water, the product will occupy a smaller volume. On the other hand, if a preservative treatment is applied to the concentrate, the latter can also be stored for a longer time.

When drinking water is added to the concentrate to make this type of juice, the water must be added in an amount equal to that removed, and therefore **the juice** prepared from the concentrate **must contain the same Brix level value as the original juice**.



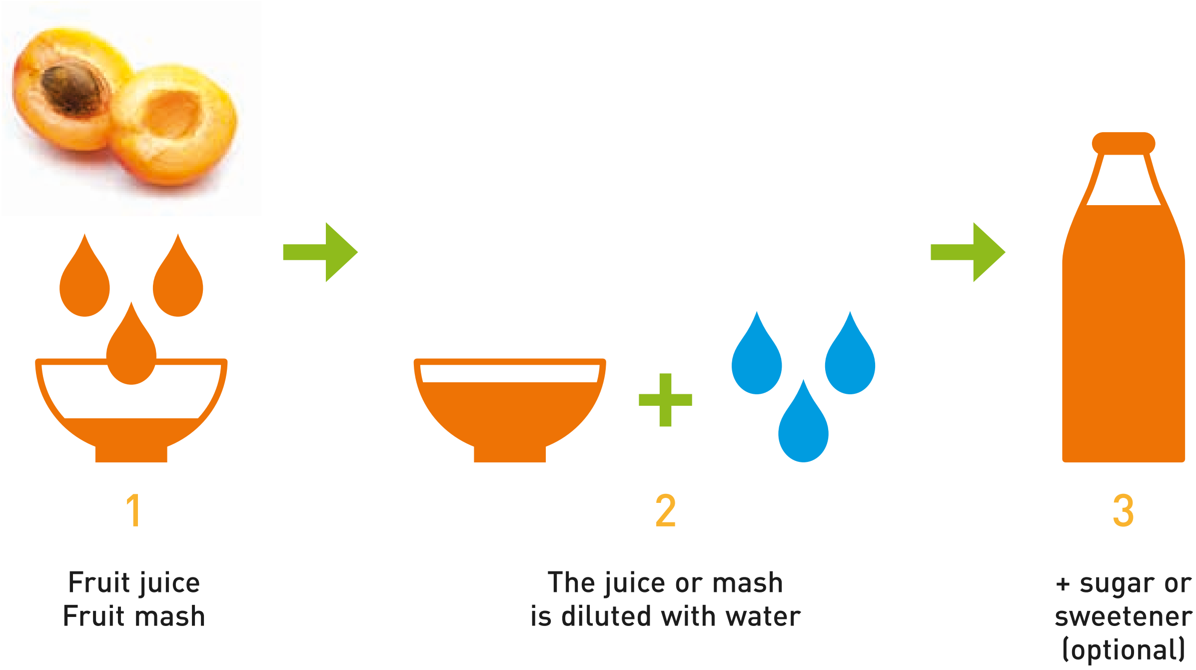
5.2.3. Water extracted fruit juice

This category includes two kinds of juice:

- juices obtained from whole dehydrated fruits, as in the case of prune juice, where the fruits are rehydrated in drinking water and then crushed.
- the other type of juice is juice that has been obtained by diffusion in water, as in the case of bissap; the dehydrated fruits (or here, the flowers) are steeped in drinking water and the resulting juice is then filtered.

33 The Brix scale is used to measure the concentration of dissolved solids in a liquid. It is based on the refraction of light and its measurement is performed using a refractometer.

5.2.4. Fruit nectar

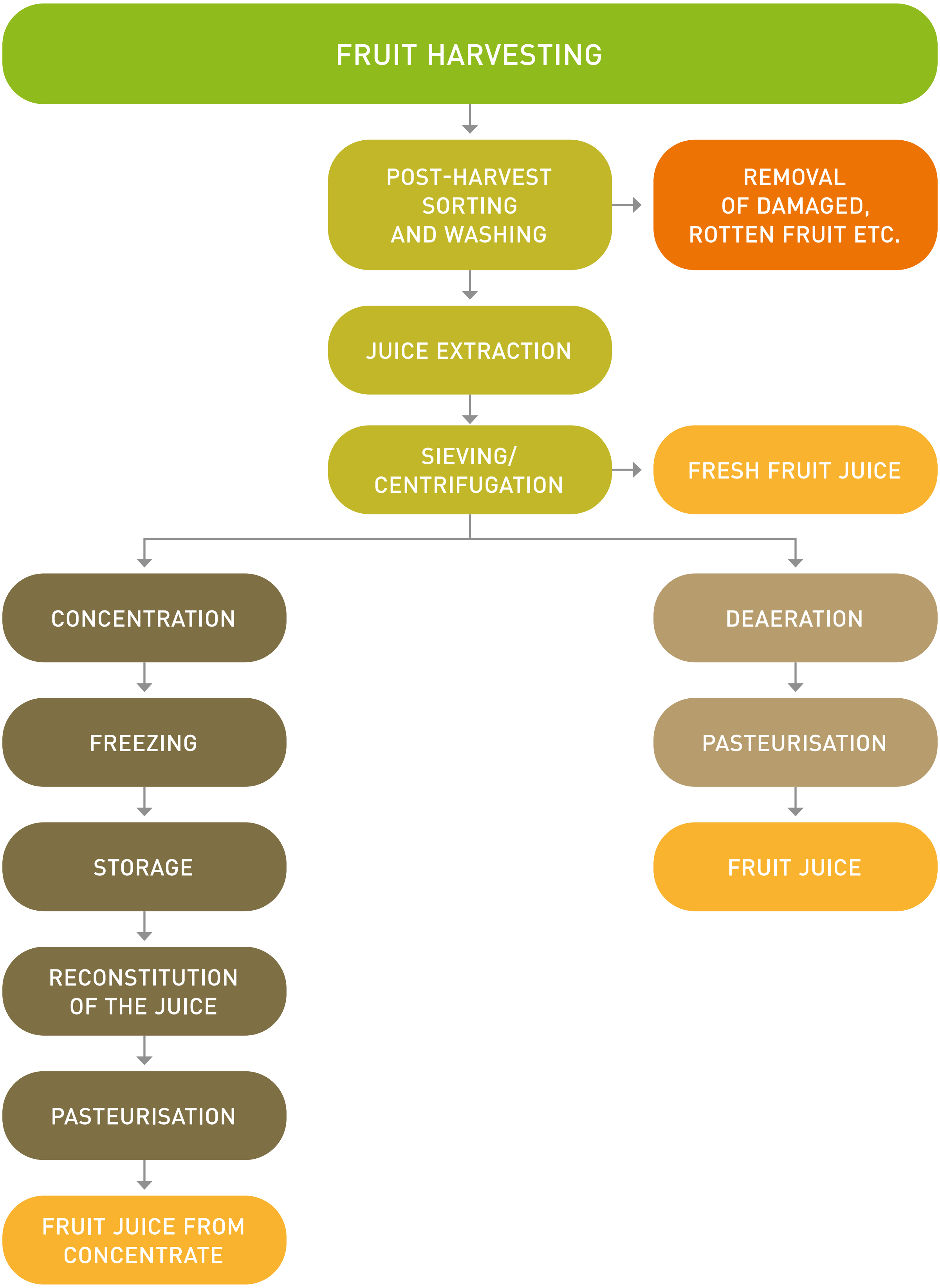


Nectar is produced from fruit juice, fruit juice concentrate or fruit purée by adding drinking water to it as well as sugar, syrup, honey or sweeteners, if necessary.

Usually, **fruits used for making nectars are very pulpy**, like bananas, apricots, peaches and pears, or sour, like red fruits. It is therefore essential to dilute them with water and then sweeten them in order to obtain a drinkable drink. The minimum fruit content of nectars is regulated and ranges from 25 to 50% depending on the variety of the fruit.

5.3. JUICE PREPARATION METHOD

The general and most common process for making the different types of juices (fruit juices and fruit juices from concentrate) is detailed below. The important points regarding the main stages will be revisited.



5.3.1. Operations in the preparation of "fresh fruit juices" and common to all types of fruit juice

5.3.1.1. Harvest stage

Special attention should be paid to the fruit from the harvest stage in order to achieve a high-quality product. The picking of fruit takes place during the harvest. Regardless of the product and where it comes from, the picking stage is hugely important. Indeed, this takes place when the fruit is at the ideal level of ripeness. When harvesting, it is therefore important to **select the fruits carefully** in order to choose fruits **at their optimum ripeness, when the sugar, juice and aroma levels are at their highest**, *i.e.* when their nutritional and taste properties are optimal.

It is therefore essential to train the workers responsible for the harvest in terms of fruit selection, and also to minimise damage to the fruit. Indeed, when fruit is handled and stored in boxes during the harvest it can easily be damaged. Damage can be observed (cuts and holes) through which bacteria and fungi can enter the fruit and develop, causing it to rot.

Improper handling or mishandling can also be responsible for the appearance of bruising, traces of which will not appear until several days after harvest. These bruises are often due to impact, compression during storage or abrasion due to friction. To minimise the occurrence of trauma and bruises, **processing plants should be located close to production sites** in order to reduce transport times and the risk of impact. Usually picked near to the production sites, the fruits are pressed within 24 hours of harvest. The juice or purée obtained is then stored at low temperature in barrels or in a tank and transported to the packing site without breaking the cold chain. Flavour and nutritional properties are thereby preserved.

5.3.1.2. Post-harvest sorting and washing

After harvesting, it is important to remove any fruit showing signs of putrefaction, trauma, etc. Damaged or even rotten fruit can cause visual or taste defects in the product when pressed.

It is also important to sort through harvested fruit for health reasons, because some types of mould can lead to the production of mycotoxins. Any fruits discarded during this sorting process may then be used in different ways depending on the type of fruit in question and possibly the causes of their removal (for cattle feed only if they do not present a health risk, composting, anaerobic digestion, destruction, etc.).

Once sorted, the fruits are washed with clean water (not necessarily drinking water) to remove any impurities present (dust, earth, etc.).

5.3.1.3. Juice extraction

It is at this stage that the juice is extracted using mechanical processes. The fruits are pressed or crushed depending on the type of fruit. To increase extraction yields, it may also be beneficial to cut or grind the fruit into smaller fractions to increase the efficiency of the press. Heating the ground material to 50°C can also be effective in increasing the yield: this will allow the juice to flow more easily from the fruit by reducing its viscosity.

Depending on the type of fruit, this stage must or may not be preceded by a peeling and pitting stage (e.g. mangoes).

5.3.1.4. Sieving and centrifugation

These stages are optional and depend on the types of fruit used and the desired end product. These stages mainly relate to fruit juices containing solid residues which are undesirable in fruit juices. These physical processes can therefore make it possible to remove elements such as seeds or excess pulp in the case of very pulpy juice (sieving) or if the desired product is a product without pulp (centrifugation).

Following this stage (if necessary), the fruit juice obtained can be bottled and sold under the designation "fresh fruit juice". It is important to note that this type of juice can only be stored in the fridge (4°C) for a very limited period (3-4 days).

This stage is the last common to fruit juices and fruit juices from concentrate.

5.3.2. Operations for the preparation of "fruit juice"

5.3.2.1. Deaeration

This stage will remove the gases present in the juice, specifically oxygen. The advantage of removing oxygen is that it limits the oxidation process. In fruit juices, oxidation can have multiple negative effects:

- denaturing of molecules of interest sensitive to oxidation, such as ascorbic acid (vitamin C);
- appearance of an undesirable colouration (brownish), due in particular to reactions such as enzymatic browning;
- appearance of undesirable tastes, relating to browning reactions or the oxidation of aromatic molecules such as terpene.

This oxidation phenomenon takes place in the presence of oxygen, light and moderate heat. **Tropical conditions are therefore favourable** for oxidation reactions and means to prevent this reaction must be put in place to achieve a quality product. This deaeration stage is therefore one of the means of limiting this reaction by removing (as much as possible) one of the causes of oxidation.

In artisanal production, this step is rarely put in place given the necessary equipment requirement. Artisanal fruit juices are therefore more sensitive to oxidation and it will be essential to play on other levers to limit the phenomenon of oxidation.

It is possible to, for example:

- lower the pH of the fruit juice (increase acidity) by adding acidifying ingredients, such as lime or lemon juice;
- minimise the amount of air present in the final packaging;
- use opaque packaging to prevent light from catalysing this reaction;
- keep fruit juices cold to slow down the reaction;
- use heat treatments (such as pasteurisation), which will also have an effect by destroying a large proportion of the enzymes responsible for enzymatic browning.

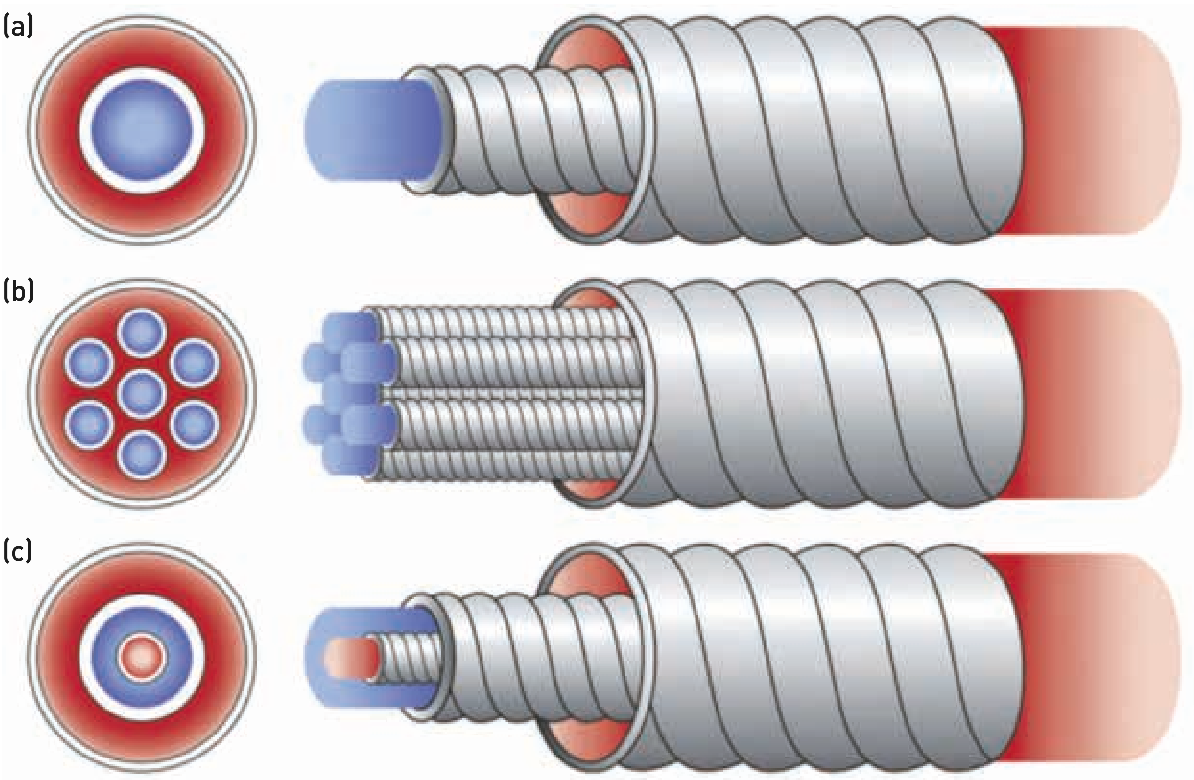
In industrial production, the most widely used methods are spraying or thin-film coating in a vacuum chamber.

5.3.2.2. Pasteurisation

To destroy most micro-organisms (and all pathogens) as well as the enzymes responsible for degradation, it is necessary to apply a preservation treatment. Pasteurisation is the most widely used preservative treatment in the manufacture of fruit juices.

Fruit juices can be pasteurised using a **tubular or plate pasteuriser**. There are different types of tubular heat exchangers:

- monotube and multitube exchangers: the food product circulates in one or more pipes in the centre and the thermal fluids circulate in the outer section;
- annular heat exchangers: the thermal fluid circulates in two pipes, one central and one external annular pipe; the food product is propelled through an intermediate annular channel.



Fluid circulation in monotube (a), multitube (b) and annular (c) tubular exchangers

In these types of pasteurisers, **the juice and hot water flow against the current**: this allows a gradual rise in the heat of the juice and maximises heat exchange.

When using pasteurisers, the **appropriate pasteurisation "scales" must be selected.**

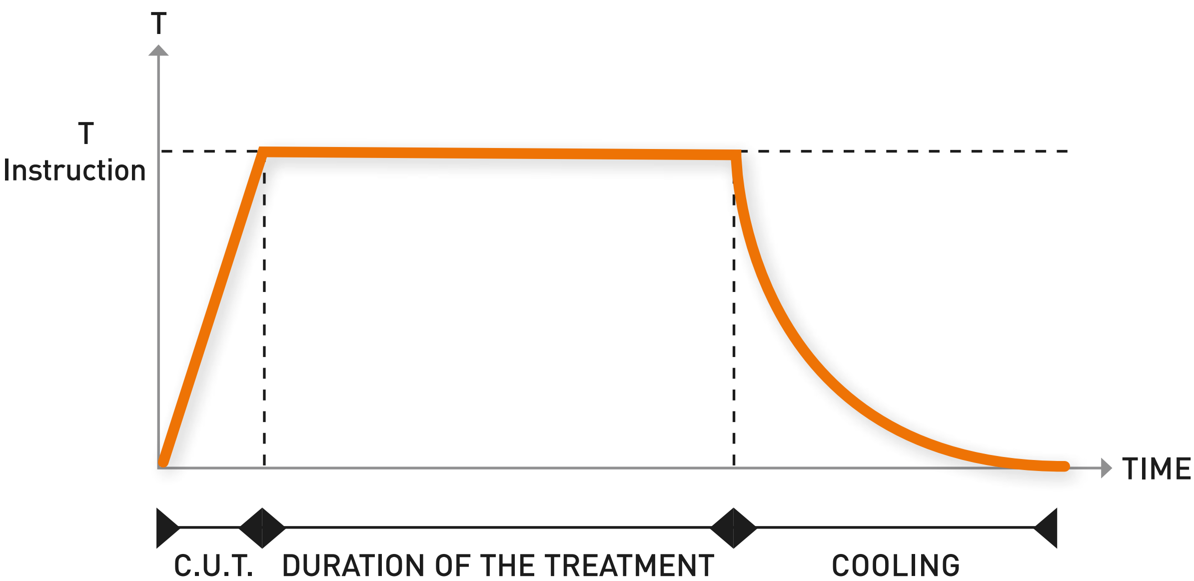
Pasteurisation scale: this is the **time/temperature pair** for each product. The pasteurisation value (P-Value)is used to compare the scales. The P-Value is the time, at 70°C, corresponding to the same efficiency as the scale used.

Pasteurisation generally involves temperatures between 65 and 95°C. Time/temperature scales **also depend on product characteristics, such as acidity.** For example, an acidic fruit juice (pH <4.5) can be pasteurised using the following scales:

- 65°C for 30 minutes,
- 77°C for 1 minute,
- 88°C for 15 seconds,
- or even 97°C for 10 seconds for a fruit juice using a tubular exchanger.

Lower temperatures consume less energy and prevent the product from heating up too much, however they take more time. **A compromise must therefore be found** between these two parameters to ensure the efficiency of the treatment while maintaining the productivity and the quality of the product.

It should however be noted that scales using higher temperatures are used with very short exposure times (e.g. 107°C for 3 seconds): this is referred to as flash pasteurisation. This type of pasteurisation must be **followed by a rapid cooling phase**, also using a tubular or plate exchanger.



It is important to note that if the product is packaged in heat resistant material, it is possible to pour the juice into its container and pasteurise everything. Pasteurisation can therefore also form the final stage of manufacturing.

The main disadvantage of this method is that in order to achieve an effective core pasteurisation temperature, it is necessary to use a higher temperature at the periphery, often for a longer time.

This can have a detrimental effect on the product by "cooking" the outer product, which induces a change in colour and taste. This method, relating to canning, was widely used until the 1960s. As the most simple method requiring the least material, it is now the method most commonly encountered in home production.

To reach a core temperature of 60-70°C, the time that the bottles spend in hot water (80°C) depends on the volume of the container used (see table below).

Bottle volume	Time required
33 cl	10 minutes
50 cl	15 minutes
75 cl	20 minutes

This method can be carried out in a water bath, but requires working in batches. The disrupted production leads to a waste of time and reduced production output.

This method has been mechanised using a continuous pasteurisation tunnel with a pressurised steam spray system. In this tunnel, the product is continuously rotated to reduce the risk of a baked effect on the periphery.

5.3.3. Operations for the preparation of "fruit juice from concentrate"

5.3.3.1. Concentration stage

This stage involves removing some of the water from the juice. This concentration should be at least 50%. To do this, the juice is heated to allow the water to evaporate. To **avoid the development of a "cooked" taste** and excess modification of the aromatic molecules, evaporation often takes place by heating under vacuum, in order to reduce the temperatures. To completely remove this "cooked" taste, the concentration process can also be achieved by using the principle of reverse osmosis. The phenomenon of reverse osmosis is the opposite of natural osmosis. To achieve reverse osmosis, sufficient pressure must be applied to reverse the tendency of the water to flow towards the more concentrated solution.

The real benefit of concentration is to reduce the cost of storage and transport by reducing the volume of the juice. This process is therefore advantageous for products manufactured far from their areas of consumption. However, the concentration process induces an aromatic modification of the product and will therefore not (or rarely) be used where manufacture takes place in the consumption area.

As artisanal production is mostly linked to local consumption, this type of fruit juice is rarely associated with this type of production.

5.3.3.2. Freezing - storage

Depending on the temperature to which the concentrate has been heated and the storage (or transport) time required before continuing the process, the concentrate may be stored as is or frozen until use.

Freezing is preferred where the concentration process has not been carried out at sufficient temperatures to destroy micro-organisms or if sterile storage conditions cannot be ensured. Freezing involves holding the concentrate at a temperature of -18°C. At this temperature, micro-organisms can actually survive, however they cannot multiply. Freezing cannot therefore reduce the quantity of micro-organisms present, but it does stop their activity during the freezing process. Consequently, freezing does not in any way replace a preservation process (pasteurisation, sterilisation, microfiltration, etc.).

Frozen products **must therefore be safe at the outset** and not contain too high a microbial load.

5.3.3.3. Reconstitution of the juice

Once the concentrate has been transported or stored for the desired time period, the juice must be reconstituted. To do this, it is necessary to add the same quantity of drinking water as the quantity of water removed during concentration and then to rehomogenise everything.

To ensure that the correct amount of water is added, **it is necessary to measure the Brix level value of the juice before concentration and seek to obtain the same value during reconstitution**.

5.3.3.4. Pasteurisation

In order to produce a safe product, the fruit juice is pasteurised before packing. The principles are the same as those detailed previously.

5.4. PACKING FRUIT JUICES

To achieve a quality product, suitable packing is essential. In fact, packing has an impact on the organoleptic, safety and nutritional quality of the product.

However, the difficulty in **selecting the correct packing** lies in the fact that it must not only maintain the quality of the product, but also be easy to transport and easy for the consumer to use.

Different materials can be used for packing:

- plastic: most commonly PET;
- cardboard: the cardboard boxes (e.g. cartons) in which liquids are packaged are actually made up of several layers of cardboard, aluminium and polyethylene (PE);
- metal: tin or can;
- glass.

Filling may be carried out hot, directly after pasteurisation. Hot filling is completed just after the pasteurisation stage and requires heat resistant containers. The juice is then at a temperature between 82 and 85°C. It should be noted that cooling is still necessary if the juice has undergone flash pasteurisation. The temperature of the juice will allow the container to pasteurise without having to process it further, provided that the inside of the container comes in full contact with the hot juice. The hot filled fruit juice must then undergo a cooling stage to avoid a “cooked” taste.

For materials which are unable to withstand heat, **the filling process can be carried out cold**, following a refrigeration stage. The latter is carried out after lowering the temperature of the juice to a temperature of 5 to 10°C. The juice is introduced into containers which must have been sterilised beforehand. This method also involves working under sterile conditions.

5.5. CHECKS TO BE CARRIED OUT DURING THE PROCESS

In this section, **only the hazards that are relevant to the production stages of fruit juice, and the specific features of this type of production, will be discussed.** However, in order to produce safe products, it is of course necessary to work under conditions which comply with Good Hygiene Practices (GHP). The prerequisites to the application of these GHP will therefore not be repeated here (staff hygiene, combating pests, cleaning/disinfection, etc.).

These specific features are of course not an exhaustive list and may vary according to the type of juice or fruit prepared or even according to the type of technique or equipment used.

5.5.1. Use of pesticides

Even before harvesting, special attention must be paid to the fruits, in particular where exposed to chemical contaminants in concentrations that would exceed the standards (limit values authorised by the legislation for heavy metals present in the soil or provided by fertilisers; mycotoxins; nitrates; pesticide residues, etc.).

Therefore, if **plant protection products** (such as pesticides) are used on crops prior to harvest (or even post-harvest, such as fungicides on bananas), it is necessary to respect the Good Practices for the use of these products (GAP and GPPP). The type of product, the quantity and the time delay before harvest are fundamental parameters to avoid contamination of the consumer. Misuse of these products, or the use of a product that is not authorised on the crop, can lead to **exceeding the MRLs in the final product, leading to product non-compliance** (withdrawal/recall), or even - depending on the case - present a real risk to the consumer. The MRLs to be observed are those of harvested fruits, before processing (e.g. at the time they enter the processing plant). The MRL value in fruit juices should not be referenced unless it has been previously established for this substance in juices.

Heating will not necessarily reduce the content of pesticide residues, nor the concentration of heavy metals (e.g. Cd, Pb) or mycotoxins. It is therefore important to measure these parameters in the raw materials, and **make their receipt a CCP** with regard to these parameters (check the maximum limits are not exceeded).

5.5.2. Post-harvest sorting and washing

As described above, special attention should also be paid to the fruits at the time of harvest. **The fruit must be in good condition** to prevent any contamination by pathogenic or undesirable metabolites. Therefore, fruit with bruises, damage or areas of mould must be removed during the sorting stage. This should be done in particular to prevent pathogenic organisms or mycotoxins from being present in the end product.

5.5.3. Water use

The water used during manufacture or for any operation inducing contact between the water (or the sprayed surface) and the product must be clean water (for washing only) or water that respects the WHO standards defined for drinking water (in the other stages) in order to avoid contamination by micro-organisms or chemicals.

Indeed, water can be a vector of different types of biological (coliform, salmonella, etc.) or chemical (nitrates, heavy metals, pesticides, etc.) contaminants. Contamination via water can take place at any stage where water is used.

However, **the most critical stage is the dilution of the fruit concentrate when reconstituting the fruit juice from concentrate**. Indeed, at this stage, water is added in relatively large quantities which will be directly consumed by the consumer.

5.5.4. Pasteurisation

One of the main risks associated with the production of fruit juice is adhering to the prescribed scale: the time and temperature of pasteurisation.

In fact, heat treatment serves mainly to destroy the pathogenic micro-organisms present. However, it is only effective if the time and temperature scales are complied with. It is therefore **essential to heat the product (to the core)** to the temperature defined by the chosen scale,and not to a lower temperature. In addition, the probe used to take the temperature of the pasteuriser must be calibrated periodically to ensure that the temperature readings of the equipment are correct.

It is however also essential to respect the time parameter of this scale and therefore not to shorten it.

Should the scale not be observed, it would be impossible to know whether the pathogenic micro-organisms have been destroyed or not, and if the subsequent consumption of the product by the consumer would pose a risk. It is therefore necessary to measure these parameters and **to make pasteurisation a CCP** in relation to these measures (check compliance with the limit values).

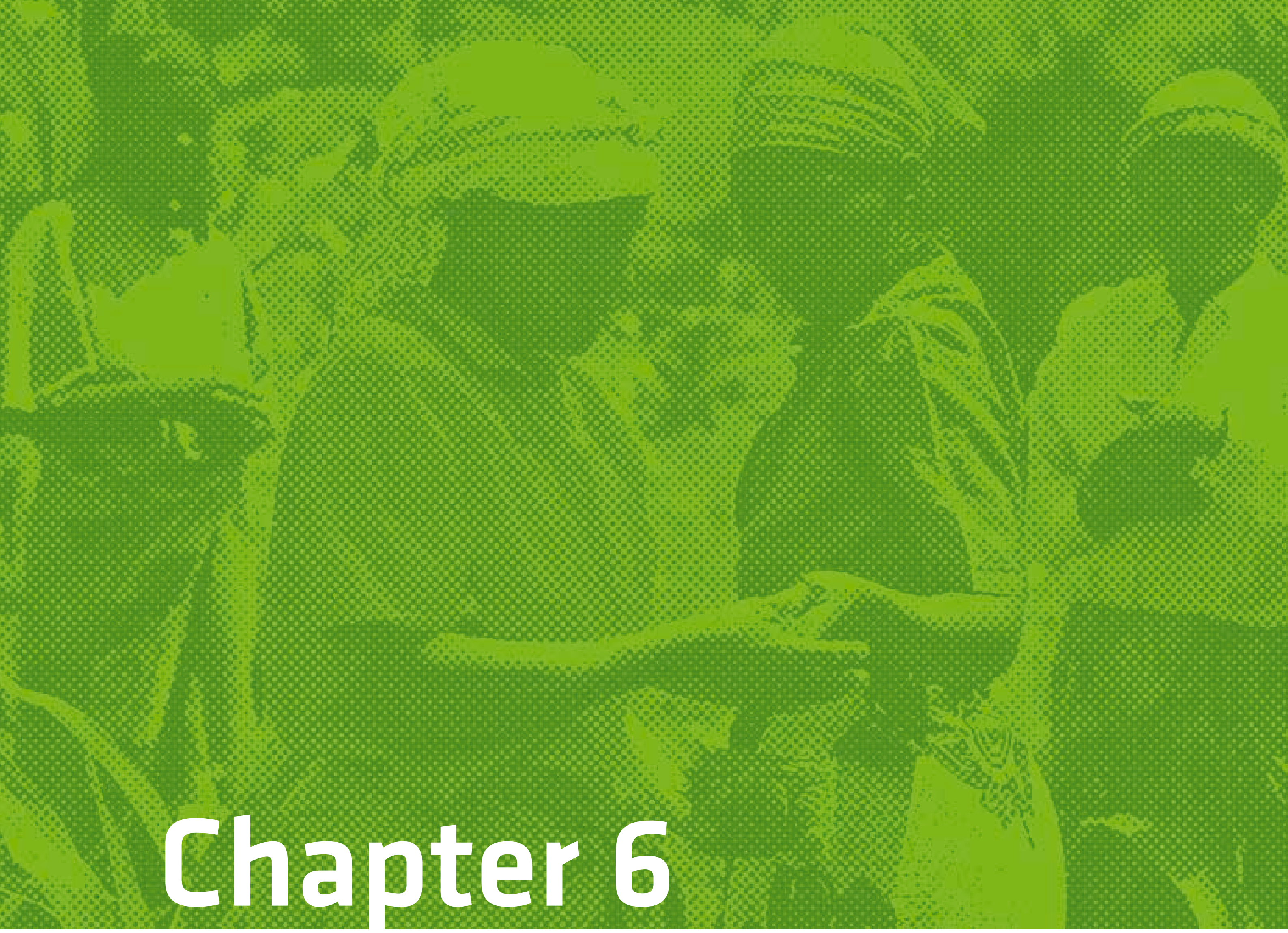
5.5.5. Glass breakage

During hot filling, one of the hazards that can occur regularly is the breakage of glass bottles, which do not withstand the heat of the product. Capping containers with a metallic lid also frequently leads to glass breakage.

It is therefore very important to work with quality materials, but also to stop filling if this should occur, in order to remove all traces of broken glass.

Summary table

Hazard	Stage	Type of hazard	Acceptable level	Preventative measures
Pesticide residues	Harvest	Chemical	Pesticide residues below the MRL defined by substance and by type of fruit	Compliance with instructions for use (GAP and GPPP)
Presence of mycotoxins (patulin, ochratoxin A)	Harvest	Chemical	Maximum concentration defined by substance	Sorting fruit, removing rotten or damaged fruit, avoiding collecting fruits that have fallen to the ground
Water contaminated by pathogens (*Vibrio cholerae, E. coli* O157:H7, salmonella, hepatitis E and A viruses, etc.)	Dilution of concentrated juices	Biological	Defined by national standards or by WHO standards	Use drinking water (water analysis)
Water contaminated by chemical substances (nitrates, heavy metals, etc.)	Dilution of concentrated juices	Chemical	Defined by national standards or by WHO standards	Use drinking water (water analysis)
Pasteurisation temperature too low, ineffective pasteurisation	Pasteurisation	Biological	Microbiological criteria defined by national standards or by the *Codex Alimentarius*	Adjusted time/ temperature scale Calibrated temperature probe
Glass breakage during packing while product is hot	Packing	Physical	No glass shards present	Use good quality equipment in good condition



Chapter 6

Preparing fruit jams, jellies and marmalades

6.1. DEFINITION AND GENERAL PRINCIPLES

Jams, marmalades and jellies are **cooked products made using fruit, vegetables or their juice.** The fruit, vegetables and juice must be safe, clean and at the right level of ripeness. However, it is important to point out that these products can be made using fresh, dried or frozen fruit.

Mango jam

Fruit must always be the main ingredient of these products. It provides specific tastes and flavours as well as colour and acidity, but also contains the compound, known as **pectin**, needed to form a gel. Pectin is a carbohydrate compound which occurs naturally in plants. It enables cells to bind together and **acts as a kind of "cellular cement".** It is important to note that not all fruit has the same pectin content. Pectin can be added (E440) to make up for the low pectin content of some fruit.

During the production of jam, the fruit and sugar mixture is heated and the pectin naturally present in the fruit is extracted. The pectin then binds together, **creating a gel: it is pectin which gives jams their distinctive consistency**.

Copper ions help this gel to form. This is why the utensils traditionally used to make jam are made of copper. Nevertheless, this practice is dying out since copper poses a potential health risk for the consumer.

Jams, marmalades and jellies are products which have **a high sugar content**. Sugar is added to increase shelf life. Indeed, just like salt, increasing the sugar content lowers the water activity (Aw). Water activity combined with pH (acidity) is one of the factors governing the activity of micro-organisms in a product. In short, the presence of water is the determining factor for many chemical and biochemical reactions. Every organism or micro-organism requires water to be metabolically active. However, some ingredients, such as sugar or salt, can bind with water, meaning that it is not available for those reactions. The more compounds there are in the product which can bind with water, the more the water activity will reduce and the more inactive and unable to multiply micro-organisms will be. However, although a fall in water activity helps initially to decrease the activity of micro-organisms and enzymes, it can then encourage other reactions such as the oxidation of fats and the Maillard reaction.

In jams, adding a high quantity of sugar helps to reduce water activity to a **value of 0.84-0.85**. It is therefore important to add enough sugar to the product to ensure good preservation. Nonetheless, reducing the water activity **is not enough to completely stop the activity of micro-organisms**, especially yeast and mould. As a result, it is possible to see these develop on these products.

To achieve the objective of lowering the water activity, sweetening ingredients are permitted during their preparation, including[34]:

- Sugar (sucrose),
- Fruit sugar,
- Fructose syrup,
- Brown sugar,
- Honey.

Jam is also the result of a relatively long cooking process. The decreased water activity is therefore combined with heat treatment to destroy the micro-organisms in the mixture (fully or partially dependent on the length and temperature of the cooking).

The **combination of these two preservation methods** gives these products a relatively long shelf life (providing they are not opened).

Fruit and sweetening ingredients are the basic components of these products. However, other ingredients may be added such as aromatic herbs, spices or nuts (beware however that some people are allergic to nuts).

34 For the European market, Council Directive 2001/111/EC states which sugars are suitable in food for human consumption and may be used: semi-white sugar, white sugar, extra-white sugar, sugar solution, invert sugar solution, invert sugar syrup, glucose syrup, dried glucose syrup, dextrose monohydrate, dextrose anhydrous, fructose, brown sugar and sugar extracted from fruit.

6.2. CHARACTERISTICS OF DIFFERENT PRODUCTS

6.2.1. Jam

Jam is a product made using whole or chopped fruit, pulp and/or purée concentrate or not-from-concentrate purée of one or more fruits mixed with sweetening ingredients.

Drinking water may be added to jam to obtain the right consistency. However, it is also important to comply with the quality criteria, which states that the proportion of soluble dry matter (mainly referring to sugar) must be between 60 and 65% or more.

6.2.2. Jelly

Jelly is a product made using juice and/or aqueous extracts of one or more fruits mixed with sweetening ingredients.

Drinking water can be added to jelly to obtain a semi-solid gelled consistency. However, as with jams, the proportion of soluble dry matter must be between 60 and 65% or more.

6.2.3. Marmalade

The term "marmalade" is generally used for products made using citrus fruits. Citrus-based marmalade refers to products made using citrus fruit (peeled or unpeeled whole or chopped fruits, purée, zest, pulp or juice) mixed with sweetening ingredients and brought to the right consistency.

Citrus-based marmalade must consist of a minimum of 20% fruit, including at least 7.5% for the endocarp (the flesh of the citrus fruit).

Citrus-based marmalade can also be referred to as citrus-based jelly marmalade when all the insoluble dry matter has been extracted (small quantity of sliced peel permitted).

Products labelled as marmalade but made with non-citrus fruits must be made by cooking whole, chopped or crushed fruits, mixed with sweetening ingredients until they obtain a semi-liquid or viscous consistency. Fruit marmalade must have a **fruit content of at least 30%**, except for ginger, which must have a minimum content of 11%.

6.2.4. Fruit content of different products

The fruit content of different products can also be used to determine the quality of jams and jellies. The terms "**extra jam**" or "extra jelly" can be used to describe products with a higher fruit content than traditional jams and jellies.

6.2.4.1. Extra jams and jellies

To be labelled as an extra jam or jelly, the product must contain **at least 45% fruit with the exception of certain fruits**:

- Mango, rambutan, roselle, sorb, sea-buckthorn: 35%;
- Soursop and cranberry: 30%;
- Banana, ginger, guava, jackfruit, sapodilla, cempedak: 25%;
- Cashew apple: 23%;
- Durian: 20%;
- Tamarind: 10%;
- Passion fruit and other highly acidic fruits: 8%.

The sugar content must therefore be 50-55%. It is important to remember to add enough sugar, since it is the preservative used in these products. If the sugar content is too low, the water activity could be too high, leading to a greater likelihood that micro-organisms will develop.

6.2.4.2. Other jams and jellies

For standard jam and jelly (not "extra"), the product must contain at least 35% fruit, with exceptions for certain fruits:

- Mango, rambutan, roselle, sorb, sea-buckthorn: 25%;
- Soursop and cranberry: 20%;
- Cashew apple: 16%;
- Banana, ginger, guava, jackfruit, sapodilla, cempedak: 15%;
- Ginger: 11-15%;
- Durian: 10%;
- Tamarind, passion fruit and other highly acidic fruits: 6%.

The fruit content is identical for fruit jellies and jams. However, for jellies, and mainly those made using aqueous extracts, it is important to take into account the amount of water added to the product.

6.2.5. Additives permitted in jams, marmalades and jellies

When these products are handmade, very few additives are used (e.g. pectin and acid). However, for industrial production, the most commonly used authorised additives are:

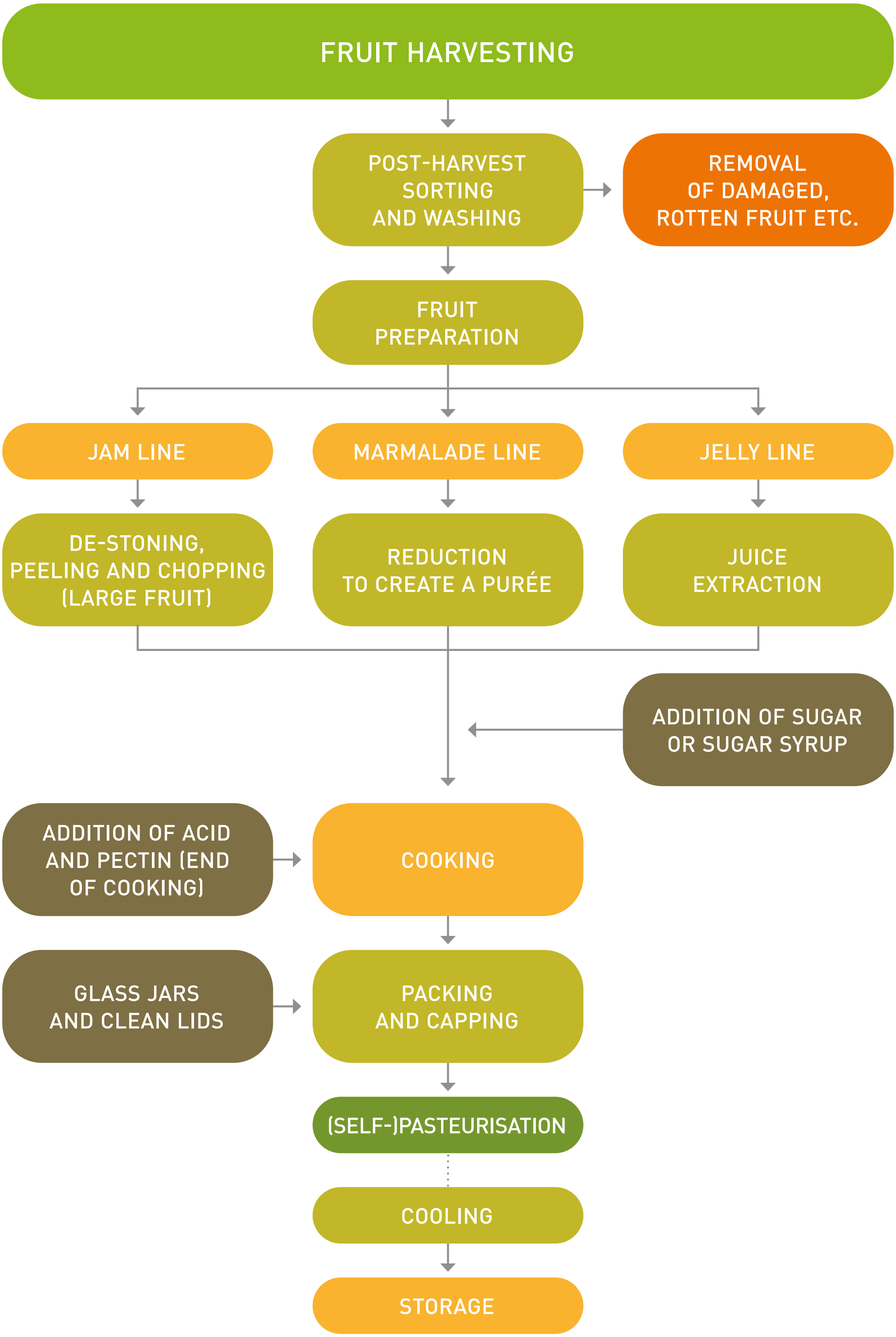
- Thickeners (pectin E440): thicken products and make them more solid;
- Acidity regulators (citric acid E330; ascorbic acid E300): make products safer, give them a fresher taste and sometimes prolong their shelf life;
- Antioxidants (ascorbic acid E300): limit spoiling of food and prevent products from discolouring;
- Colourants: give products a colour in order to make them more attractive; the only authorised colourant is red beetroot juice E162. However, this is only permitted to boost the colour of jams;
- Preservatives (lactic acid E270): these are becoming increasingly rare. They combat the growth of bacteria, fungi and yeast, which gives food a longer shelf life.

There are nonetheless many other types of additive, such as sweeteners or speciality sugars for "sugar-free jams" suitable for diabetics (or people trying to lose weight): E202 – Potassium sorbate; E406 – Agar; E333 – Calcium citrates; E327 – Calcium lactate; E955 – Sucralose; E331 – Sodium citrates; E960 – Steviol glycosides; E211 – Sodium benzoate; E950 – Acesulfame potassium; E509 – Calcium chloride; E420 – Sorbitol; E965 – Maltitol; E420ii – Sorbitol syrup; E440ii – Amidated pectin; E968 – Erythritol; E428 – Gelatine; E1400 – Dextrin; E410 – Locust bean gum; E100 – Curcumin; E325 – Sodium lactate; E965ii – Maltitol syrup.

6.3. METHOD OF PRODUCTION OF JAMS, MARMALADES AND JELLIES

The **general process which is most commonly used** for making jam is described below. **The process is the same for artisanal and industrial production**, although the pasteurisation stage is sometimes skipped (self-pasteurisation, *see below*).

According to the *FAO Manual*, the process for making jam, marmalade and jelly can be set out as follows:



The stages involving the preparation of fruits do not apply to jellies since they are made using fruit juice. However, the cooking and packing stages are identical.

6.3.1. Operations for preparing fruit to make jams and marmalades

6.3.1.1. Harvest stage

Special attention should be paid to the fruit from the harvest stage in order to achieve a high-quality product. The picking of fruit takes place during the harvest. Regardless of the product and where it comes from, the picking stage is hugely important. Indeed, this takes place when the fruit is at the ideal level of ripeness. During the harvest, it is important to **select the fruit carefully** to ensure that it is **at the optimal level of ripeness, when the levels of sugar, juice and flavour are at their highest**, *i.e.* when it has optimal nutritional and flavour properties.

It is therefore essential to **train operators picking the fruit** to ensure the correct fruit is selected and damage to fruit is minimised. Indeed, when fruit is handled and stored in boxes during the harvest it can easily be damaged. Damage can be observed (cuts and holes) through which bacteria and fungi can enter the fruit and develop, causing it to rot.

Poor handling and storage can also cause bruising, which only appears several days after the harvest. These bruises are often due to impact, compression during storage or abrasion due to friction. To minimise damage and bruising, **processing workshops must be located close to the production sites** to reduce the transport time and risks of impact.

6.3.1.2. Post-harvest sorting and washing

After the harvest, it is important to separate out the fruit with signs of rotting, damage, etc. Indeed, damaged and rotten fruit can lead to defects in the appearance or taste of the product if it is processed.

It is also important to sort through harvested fruit for health reasons, because some types of mould can lead to the production of mycotoxins. The fruit separated out during this sorting stage can then be disposed of in various ways depending on the type of fruit and the reasons for it not being used in the product (food for livestock if there is no health risk, compost, biomethanisation, destruction, etc.).

The fruit then **needs to be washed using clean water** to get rid of impurities on its surface (dust, soil, etc.). Fruit can be cleaned in two ways:

- By spraying: a jet of water is sprayed directly onto the fruit,
- By immersion: the fruit is immersed in water.

The method chosen depends on the fragility of the fruit in question.

6.3.1.3. De-stoning, peeling and chopping

Depending on the type of fruit used to make the jam, some fruit, like mangoes, first need to be peeled and de-stoned to get rid of the inedible parts of the fruit. The following operations need to be carried out:

- **De-stoning**: the stones can be removed using a needle destoner machine. This machine has a drum with rows of dimples in which the fruit is positioned. These dimples then pass under the needle cutter which pierce the fruit and remove the stones. The stones need to be removed carefully to prevent **shards of stone** from remaining in the product, which would pose a risk to the consumer. These stones can then be reused in another sector (recycling of by-products).
- **Removing inedible parts.**
- **Removing stalks.**

Some large fruits, like mangoes or pineapples, need to be chopped up before cooking to ensure consistent and fast cooking.

6.3.2. Common preparation steps for jams, jellies and marmalades

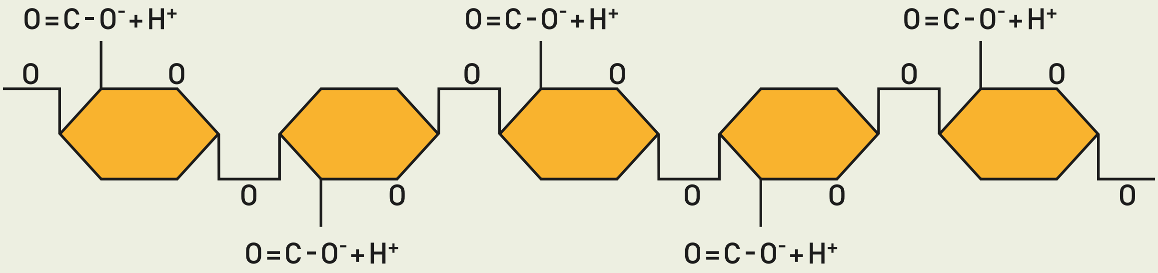
6.3.2.1. Mixing and gelling

Once the fruit has been prepared (or the fruit juice in the case of jelly), it is **mixed with sugar and pectin** where necessary. The mixers used differ depending on whether the process involves whole or chopped fruits. Whether whole fruits (e.g. strawberries or raspberries) or fruit pieces (e.g. plums) are used, they should be as intact as possible in the jam. For this reason, mixers with radial paddles or a helical blade are used.

Pectin is one of the gelling agents added (E440). It is a natural gelling substance found in fruit. Some fruit is naturally very high in pectin, such as apples, berries (except strawberries), quinces, orange and lemon peel, while others contain very little, such as cherries, strawberries and pears. It is industrially extracted from by-products of the fruit juice industry, mainly from citrus fruits and, to a lesser extent, pressed apples.

Pectin is available as a fine powder or ready-mixed with sugar to be used in jams and jellies. To ensure that it dissolves as best as possible, it is advisable to mix it with sugar in advance at the rate of 10 to 15 grams of pectin to each kilogram of sugar.

Pectin is made up of a complex combination of macromolecules. It is made up of a main chain with secondary chains branching off. The monomers are varied as are the branch types. The main chain is made up of galacturonic acid (an acid polymer).



The water molecules contained in the jam are bound by the hydrogen bonds in the hydroxyl groups of the polymethylgalacturonic chain. Moreover, pectin molecules have a negative electrical charge, which means that they stretch out, thus increasing the viscosity of the solution, and they repel each other. These factors combine to keep the molecules spread out.

When the charges and hydration are reduced, the pectin filaments tend to solidify. They move closer, link up and form a three-dimensional solid network which holds the liquid phase inside. In the case of jams (highly methylated pectin), the level of hydration is reduced by the addition of sugar and the reduction of electrical charges by **the H+ charges supplied by the acidity of the fruit and the acid added.** The weak bonds (electrostatic hydrogen bonds) give the gel a high level of plasticity.

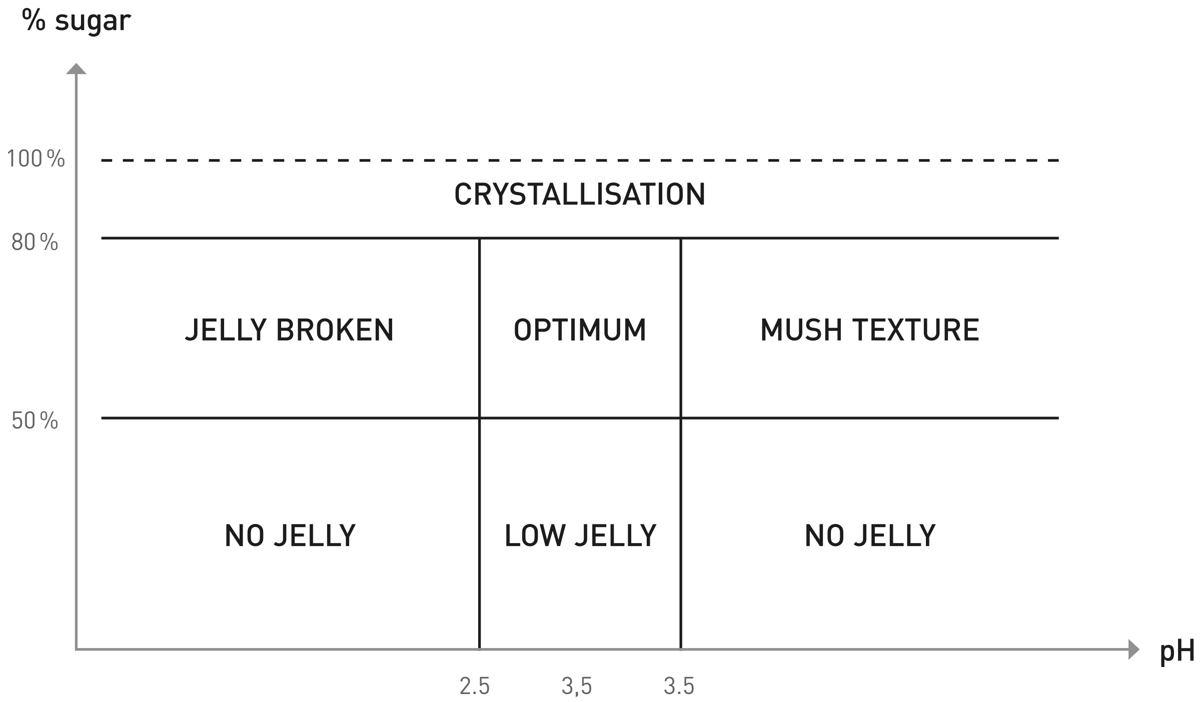
Therefore, since pectin needs acidity to be activated, it is necessary to add lemon juice to jams and jellies. However, citric acid is often added to the mixture after cooking also due to its **acidifying and preserving properties**.

It is important to remember that gelling depends on three factors:

- Pectin content,
- Sugar content,
- pH.

The right balance between these three factors is essential to achieve good gelling.

pH is a key factor. In practice, it should be between 2.9 and 3.3 but this depends on the quality of the pectin. For a standardised production process, it is worthwhile using commercial pectin. Pectin is classified by its degree of methylation, which determines its use according to the speed at which the gel sets.



Gelling depending on the pH and the concentration of sugar

6.3.2.2. Cooking

Atmospheric cooking is well suited to small-scale artisanal production. It is carried out by heating a mixture of fruit and sugar in a hemispherical pan with a large opening to allow water to evaporate by boiling off.

The mixture is then **brought to the boil** to:

- Enable the water to evaporate and obtain the desired concentration,
- Cook the fruit until it reaches the optimal consistency,
- Destroy micro-organisms,
- Destroy enzymes which cause degeneration,
- Dissolve the sugar.

Cooking should also enable the pectin to be extracted from the fruit and allow the gel to form.

> **The mixture should only be boiled for a relatively short time** to avoid **overcooking,** which could have the opposite effect **by damaging the pectin, making it impossible to form a gel.**

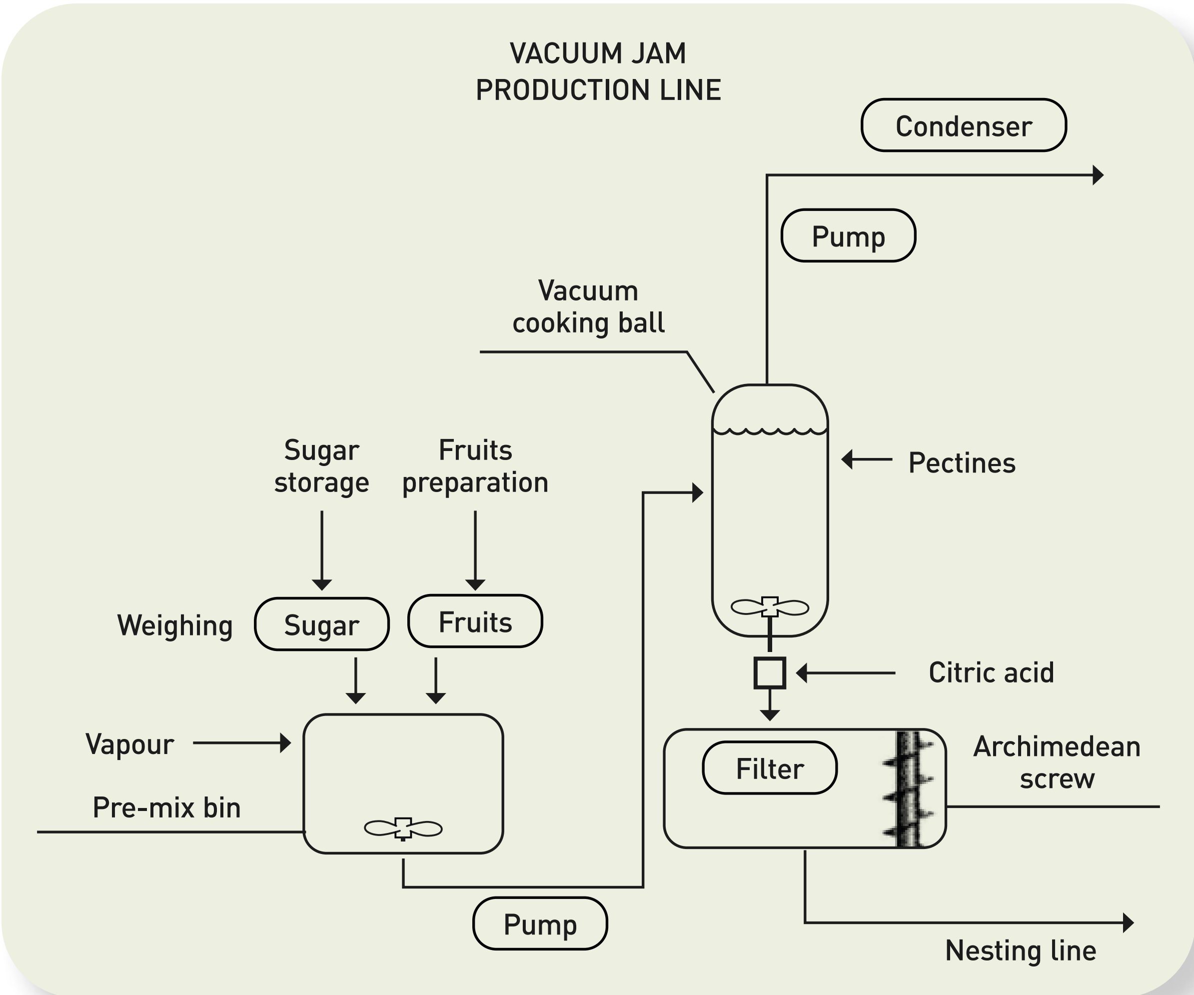
It is also important to **minimise stirring to avoid losing and destroying volatile compounds**, which lend the product its smell and taste.

Ideally, the mixture should be boiled **for 7 to 8 minutes at a temperature of 104-105°C.** The cooking temperature of jellies may be slightly higher and reach up to 110°C.

The jam manufacturing process has various stages which alter the state of the fruit. The most sensitive stage is the cooking of the fruit with the sugar. Indeed, with traditional cooking, whether in a pressurised atmosphere or not, the cell membranes are destroyed, releasing the sugars and aromas of the fruit.

As a result, some factories still use cooking pans for these products. However, the most commonly used method is now the **vacuum cooking method**.

Industrial vacuum cooker and small scale model (13 litres)



Vacuum cookers have the advantage of bringing the product to the boil at a much lower temperature. Depending on the vacuum settings, this process cooks the product and evaporates off the excess water between 50°C and 75°C. This **prevents those compounds which offer benefits in terms of nutrition and taste from being destroyed.** This process can also be used to manufacture significant quantities of jam.

The fruit and sugar are mixed in a pre-mixing vat, which has steam injected into it. After mixing, the contents of the pre-mixing vat (pre-mix) is sucked into the cooker by a pump. The stirrer in the cooking tank and the steam heater are both switched on.

The cooking tank is heated in a vacuum, and the excess water is evaporated in around 10 minutes. The water from the fruit is collected until the mixture reaches 61°Bx. Vacuum cooking is carried out, for instance, at a temperature of 65 to 75°C and a residual pressure of 30 to 40 mm Hg (40 to 53 mbar). The vacuum is then released. The temperature of the product rises sharply to 95-96°C when it returns to atmospheric pressure. **This stage enables the jam to be pasteurised without handling.** The liquid pectin is added, as per the recipe, while the stirring continues.

At 95°C, since the jam is liquid, it can flow down with gravity to the inspection vat while an acid solution (e.g. citric acid) is added. It then passes through a filter (known as a "basket") and is collected in a vat where **it is mixed by an Archimedes' screw to prevent "floating".** Indeed, since the juice has a higher density than the fruit, without mixing, the fruit would float on top of the liquid (known as "floating"). In order to obtain a consistent end product during packing, it is necessary to continue mixing constantly until the end of the process. An operator checks the conformity of the product at this stage (no burnt area, stones, stalks, correct density, etc.).

6.3.2.3. Packing

These products are packaged while they are still hot, just after cooking, when the product temperature is around 80-90°C. At this temperature, the product is liquid, **which enables it to pasteurise the container with its own heat**: this process is also known as **"self-pasteurisation".** This means that the container must be clean and heat-resistant. If it is not possible to carry out self-pasteurisation, the containers must be pasteurised in advance.

The **most commonly used packing is a glass jar with a metal lid**, which opens by twisting.

The choice of the jar is not critical, but it must have a **wide opening** so that it can be easily filled.

However, in the case of berries, which are relatively acidic, using metal tins is not advised.

The lid can be simply added after the jars are filled. The jars **must then be turned upside down so that the product, which is still hot, can also pasteurise the lid**.

Another commonly used method for this stage involves combining the capping with a **pressurised and heated steam injection.**

This steam injection also helps to destroy any micro-organisms which may be on the lid and creates a vacuum in the area between the product and the lid.

This vacuum also helps to improve the shelf life of the product.

Without this vacuum, it is important to fill the containers as full as possible to minimise the amount of air inside. Indeed, the air, and particularly the oxygen it contains, enables certain degenerative reactions to take place (**oxidation, browning**, etc.) and if micro-organisms are present, this will allow them to develop, which may have an undesirable effect on the product and pose a health risk to the consumer.

6.3.2.4. Pasteurisation

To ensure that no pathogenic micro-organism is present and that there is no risk to the consumer, jars of jam, jelly and marmalade are pasteurised. **This stage is even more important when using vacuum cooking because temperatures do not exceed 80°C**.

For these types of product, the pasteurisation stage is usually carried out after packing. The material used for packing must therefore be entirely heat-resistant.

This can be carried out using **a bain-marie**, but requires you to **work in batches in a staggered process**. This staggered process leads to time being wasted and imposes limitations on the production. Jams, jellies and marmalades packaged in **250g glass jars are immersed in boiling water for 10 minutes.**

This method has been mechanised using a continuous pasteurisation tunnel with a pressurised steam spray system. In these tunnels, the products are continuously rotated to reduce the risk of cooking the outside of the product.

Pasteurisation must be followed by a **cooling stage to stop the product heating up**, which can lead to losses in terms of both nutritional value and taste.

It is nonetheless important to note that while the pasteurisation stage is intended to ensure that there is no risk of pathogenic micro-organisms being in the product, it is not an essential stage because cooking also acts as a heat treatment. Indeed, **many producers of jam, jelly and marmalade skip the pasteurisation stage.** In this case, it is important to comply with the required cooking times and temperatures so that the task of pasteurisation is carried out effectively. It is also important to check the temperature of the product at each stage to prevent it from dropping below 80°C until the container is sealed. **This method therefore requires a level of speed.**

Moreover, in this case, if the packaged product is not pasteurised, the empty container must be pasteurised just before the packing stage.

6.4. PRODUCTION RISKS AND CHECKS TO BE CARRIED OUT

In this section, **only those hazards which are relevant to the production of jam, jelly and marmalade as well as the specific aspects of this type of production will be addressed.** However, in order to produce safe products, it is of course necessary to work under conditions which comply with Good Hygiene Practices (GHP). The prerequisites to the application of these GHP will therefore not be repeated here (staff hygiene, combating pests, cleaning/disinfection, etc.).

Of course, these specific aspects do not constitute an exhaustive list and may vary depending on the type of product or fruit in question, or the method or equipment used.

6.4.1. Use of pesticides

Even before the harvest, special attention should be paid to the fruit, especially in the event of chemical contaminants in concentrations which exceed acceptable levels (limits permitted by legislation for: heavy metals in the soil or contained in fertilisers, mycotoxins, nitrates, pesticide residue, etc.)

Therefore, if **plant protection products** ("pesticides") are used on crops before the harvest (or even after the harvest, such as fungicides on bananas), it is important to comply with the Good Practices applicable to these products (GAP and GPPP). The type of product, the dose used and the time between use and harvest are key factors to take into account to avoid contamination of the consumer. Misuse of these products, or the use of a product that is not authorised on the crop, can lead to **exceeding the MRLs in the final product, leading to product non-compliance** (withdrawal/recall), or even - depending on the case - present a real risk to the consumer. The MRLs which must be complied with are those applicable to harvested fruit before processing (e.g. when entering the factory). It is not necessary to take account of the MRL value in fruit juices, unless the value for a given substance has been previously determined for juices.

Heating will not necessarily reduce the content of pesticide residues, nor the concentration of heavy metals (e.g. Cd, Pb) or mycotoxins. It is therefore important to measure these parameters in the raw materials, and **make their receipt a CCP** with regard to these parameters (check the maximum limits are not exceeded).

6.4.2. Post-harvest sorting

As stated above, special attention should be paid to fruit during the harvest. **The fruit must be in good condition** to prevent any contamination by pathogenic or undesirable metabolites. Therefore, fruit with bruises, damage or areas of mould must be removed during the sorting stage. This should be done in particular to prevent pathogenic organisms or mycotoxins from being present in the end product.

6.4.3. Stones

If there are stones in the end product, this may be due to de-stoning being carried out incorrectly. These stones or stone fragments are foreign bodies and can have an effect on the consumer's health.

If this stage is necessary, it is important for it to be carried out correctly and for a visual check is conducted to verify the process.

6.4.4. Sugar content

"Extra" products are those with the lowest sugar content. However, the sugar content is still above 50%.

Jams, jellies and marmalades are therefore sugary products. The sugar is used for preservation by lowering the water activity (Aw), as explained above. As a result, it is essential to comply with the planned sugar content to ensure correct preservation.

Less sugary (light) recipes can be developed, but require an alternative approach and ingredients different from those used for the traditional recipes described in this manual.

6.4.5. Water use

The water used during production, or for any operation leading to contact between the water or the sprayed surface and the product, must be clean water (at the washing stage) or must comply with WHO standards set out for drinking water (at the other stages) to prevent contamination by micro-organisms or chemicals.

Indeed, water can be the vector of various types of contaminant, both biological (coliforms, salmonella, etc.) and chemical (nitrates, heavy metals, pesticides, etc.). Contamination via water can take place at any stage where water is used.

However, **the most critical stage is the preparation of the cooking mixture** where water may be added directly to obtain the desired consistency. Indeed, in this case, water is added to the product itself and will therefore be eaten directly by the consumer.

6.4.6. Pasteurisation

Pasteurisation is carried out to ensure that any micro-organisms present have been destroyed. However, it is only effective if the time and temperature scales are complied with. As a result, it is **essential to heat the product (to the centre) to the temperature set out by the chosen scale**, and not to a lower temperature. Moreover, the probe used to read the temperature of the pasteuriser must be calibrated periodically to ensure that the temperature shown on the equipment is correct.

It is also vital to ensure compliance with the time period indicated by the scale used and never to shorten the length of time stated.

Failure to comply with the scale means that it is not possible to know whether the pathogenic micro-organisms have been destroyed and the product could therefore pose a risk to the consumer. Consequently, it is important to measure these parameters and **make pasteurisation a CCP** with regard to these parameters (check compliance with the time/temperature scale).

As explained above, cooking can replace pasteurisation as a form of heat treatment. In this case, as detailed earlier, the cooking time and temperature must be complied with as well as the temperature of the product until it is packaged. In this scenario, these stages must also been deemed CCPs.

6.4.7. Glass breakage

When packing the product while it is still hot, one of the dangers regularly encountered is the breakage of glass jars which are not resistant to the heat of the product. Capping containers with a metallic lid also frequently leads to glass breakage.

It is therefore important to use high quality equipment and also to stop filling if such a breakage should arise in order to remove all traces of broken glass.

Hazard	Stage	Type of hazard	Acceptable level	Preventative measures
Pesticide residues	Harvest	Chemical	Pesticide residues below the MRL defined by substance and by type of fruit	Compliance with instructions for use (GAP and GPPP)
Mycotoxins present	Harvest	Chemical	Maximum concentration defined by substance	Sorting fruit, removing rotten or damaged fruit, avoiding collecting fruits that have fallen to the ground
Stones or pieces of stone in the end product	De-stoning	Physical	Zero	Visual checks after de-stoning stage
Sugar content	Cooking	Biological	Content >50%	Develop recipes with a sugar content >50% Comply with recipes

Water contaminated by pathogens (*Vibrio cholerae, E. coli* O157:H7, salmonella, hepatitis E and A viruses, etc.)	Cooking	Biological	Defined by national standards or by WHO standards	Use drinking water (water analysis)
Water contaminated by chemicals (nitrates, heavy metals, etc.)	Cooking	Chemical	Defined by national standards or by WHO standards	Use drinking water (water analysis)
Pasteurisation temperature too low, ineffective pasteurisation	Pasteurisation	Biological	Microbiological criteria set out by national standards or by the *Codex Alimentarius*	Adjusted time/ temperature scale Calibrated temperature probe
Glass breakage during packing while product is hot	Packing	Physical	No glass shards present	Use good quality equipment in good condition

6.5. APPENDIX: FORMULATION AND CALCULATION OF INDUSTRIAL YIELD

The manufacturing formulae used at an artisanal production level are very similar to formulae used in family-level production. The quantities of fruit and sugar used are generally the same. These formulae correspond to the "extra" quality as defined by the regulations.

In an industrial setting, the formulations 50/50, 45/55, 40/60 and 35/65 are used depending on the fruit and the quality required.

If jam is made with too little sugar, it may ferment, or, if it is cooked for too long (large quantity of water to evaporate), it will lack flavour. However, too much sugar sweetens the jam too much and overpowers the flavour of the fruit. Moreover, there is a high risk of the sugar crystallising.

Calculating the quantity of pectin to add

Example with a cherry jam with 65% dry residue.

Natural pectin content: negligible.

Using pectin at 150° Sag[35].

For 1kg of jam, there is 650g of sugar to set. Therefore, we need 650/150 = 4g of pectin.

For other fruit with higher levels of pectin, it is important to take account of the naturally-occurring pectin in the fruit. Preliminary tests can be carried out to determine the optimal quantity according to the gelling desired.

Calculating the quantity of acid

The quantity of acid which needs to be added can only be determined by measuring the pH.

As an illustration, the following values apply to fruit with low acidity levels.

For 100kg of jam	Fruit high in pectin	Fruit low in pectin
50% citric acid solution	0.175 to 0.230 litres	0.320 to 0.400 litres

35 The gelling strength is defined by the SAG value: 1g of pectin at 1° SAG can set 1g of 65% sugar solution with a pH of 3. Commercial pectin is standardised at 150° SAG.

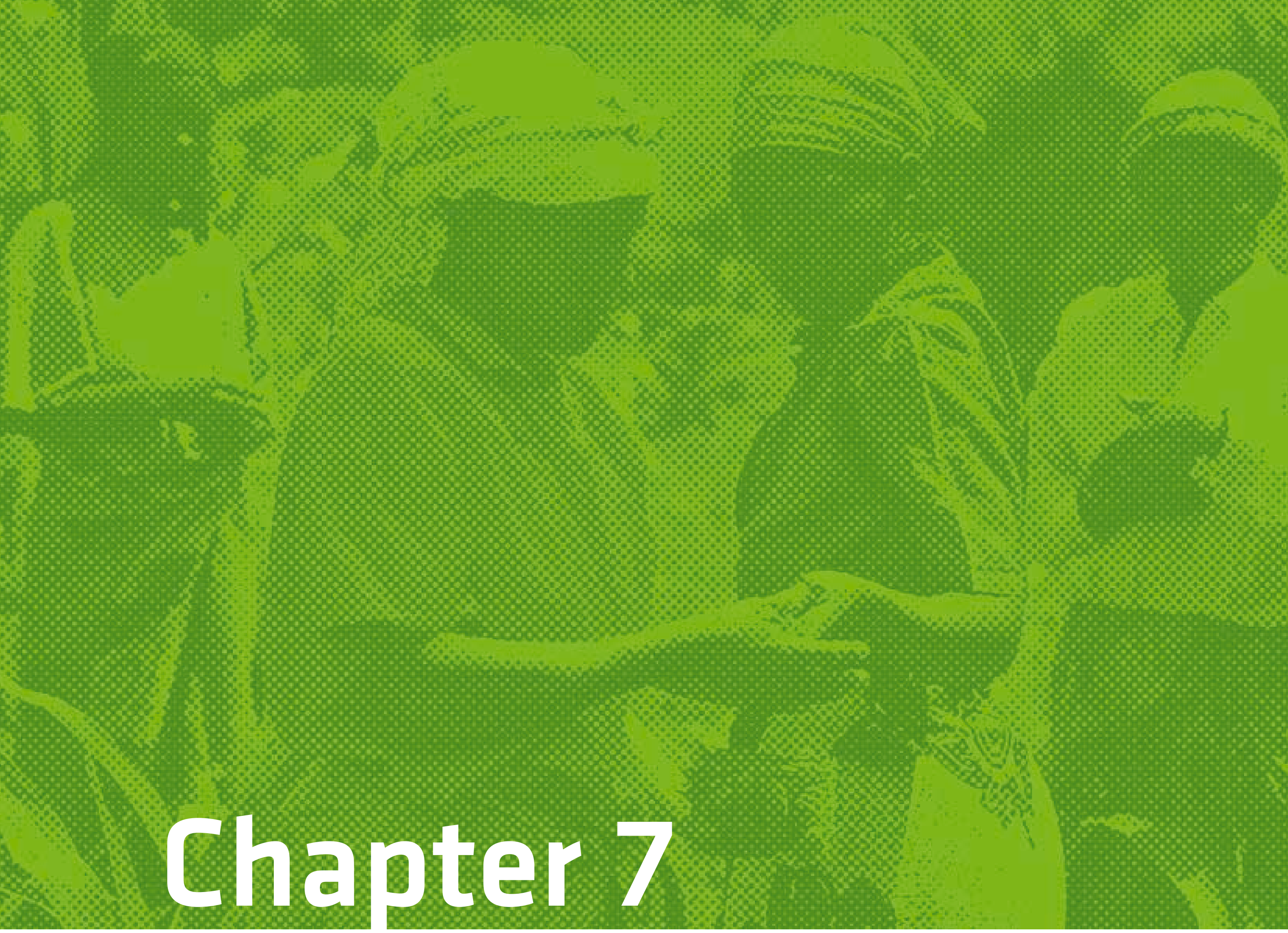
Calculating the yield

To calculate the yield, you need to know the percentage of soluble dry matter measured by a refractometer for each ingredient used. The yield is calculated by assessing the quantities of dry matter supplied by the formula compared with the rate of dry matter to be achieved.

Example for calculating the yield

Ingredient used	Weight in kg	SDM	SDM provided by the formula
Fruit or pulp	50	10	5
Sugar	50	100	50
Pectin	0.300	100	0.300
50% citric acid	0.5	50	0.250
Total	**100.8**	**55**	**550**
Yield at 65% SDM = 100 x 55.550 = 86 % / 65			

In this example, you need to cook until obtaining 86kg of jam.



Chapter 7

Preparation of dried fruits and vegetables

7.1. GENERAL PRINCIPLES OF DRYING

The technique of drying food is **the oldest and most widespread preservation method** for perishable products (meat or vegetables). Commonly used around the world, especially in the preservation of cereals and legumes, this process is becoming increasing widespread and has been used for a long time to transform **fruits** (especially mangoes, bananas, cranberries, grapes, apricots, plums, figs, apples, etc.) and **vegetables** (especially tomatoes, but also aubergines, peppers and chillies, okra, courgettes, etc.).

In many countries, traditional markets are bursting with dried vegetables and attract a large number of customers due to the flavour they bring to dishes.

Dried tomatoes, preserved in oil or otherwise, are very popular.

Dried fruit can be defined as products **prepared from healthy, ripe fruit**, treated either by sun drying or by any other recognised method of dehydration. Dried fruits are generally eaten as they are (delicacies) or they can be used as ingredients in other food products, such as mixtures of cereals (composite products: cereals with dried mango, for example, such as muesli or bars). In Europe, the trend is to consume vegetable crisps produced in the oven or in the microwave, without oil, and dried fruit mixes (preferably organic).

Dried mango

Cereal bars with mango and coconut

7.1.1. The principle of preservation is based on a reduction in water activity

The preservation process used in the case of dried products is **dehydration** obtained by **drying**. In the scientific field, more precise terms are used, according to the degree of dehydration (partial, total, even anhydrous), the methods employed (drying by evaporation, lyophilisation by sublimation, etc.) or the sectors involved (dehydration in medicine, food production, etc.).

THE FOLLOWING THREE TERMS CAN BE DISTINGUISHED

Dehydration, which generally refers to the loss of water from a body.

Desiccation, which is the process of removing water from a body to an extreme state. This is a form of dehydration aimed at removing as much water as possible. This phenomenon can be natural or forced.

Lyophilisation (or freeze-drying), which is the desiccation of a product previously frozen, by sublimation. It consists of removing water from a liquid, pastry or solid product, using deep freezing, then evaporating the ice under vacuum without melting it.

The drying process consists of **removing the excess water** present in the fruit.

As previously mentioned, the **presence of water** in the product is the most critical condition for chemical and biochemical reactions to occur, and therefore for the survival and multiplication of micro-organisms in a given matrix. To be metabolically active, any organism or micro-organism needs a certain amount of available (accessible) water. However, **it is possible to make this water unavailable** for physiological reactions, either by removing it (by dehydration), or by binding it to certain materials such as sugar or salt (hygroscopic substances, which retain water by absorption or by adsorption). In dried fruit, the decrease in water activity is usually due to dehydration only, because sweetening ingredients are not commonly added. When sweetening components are added, the end product resembles a candied fruit.

In order to extract a significant part of the water contained in the product by evaporation into the surrounding air, **it is necessary to supply energy** (**activation energy**[36]). This energy makes the water **migrate from within the product to its surface**, where it **transforms into water vapour** and is then **carried away by the outside air**. Depending on local climatic conditions, the sun and/or hot wind, or the heat from a combustion furnace may be used.

Drying makes it possible to lower an important parameter in food preservation: **water activity** (aw). To recall, the water activity of a product is always less than or equal to 1. When the water contained in a product has an activity close to 1, it evaporates in the form of pure water into the surrounding air. By analogy, this is known as free water. When the water activity of a product is less than 1, it means that all the water present in the product contributes to the stability of the chemical constituents of the product in the form of strong bonds. In order for a micro-organism or a chemical reaction to mobilise this water, it must provide sufficient energy to first break the existing bonds. This also applies to the removal of water by drying. We then speak of "bound water".

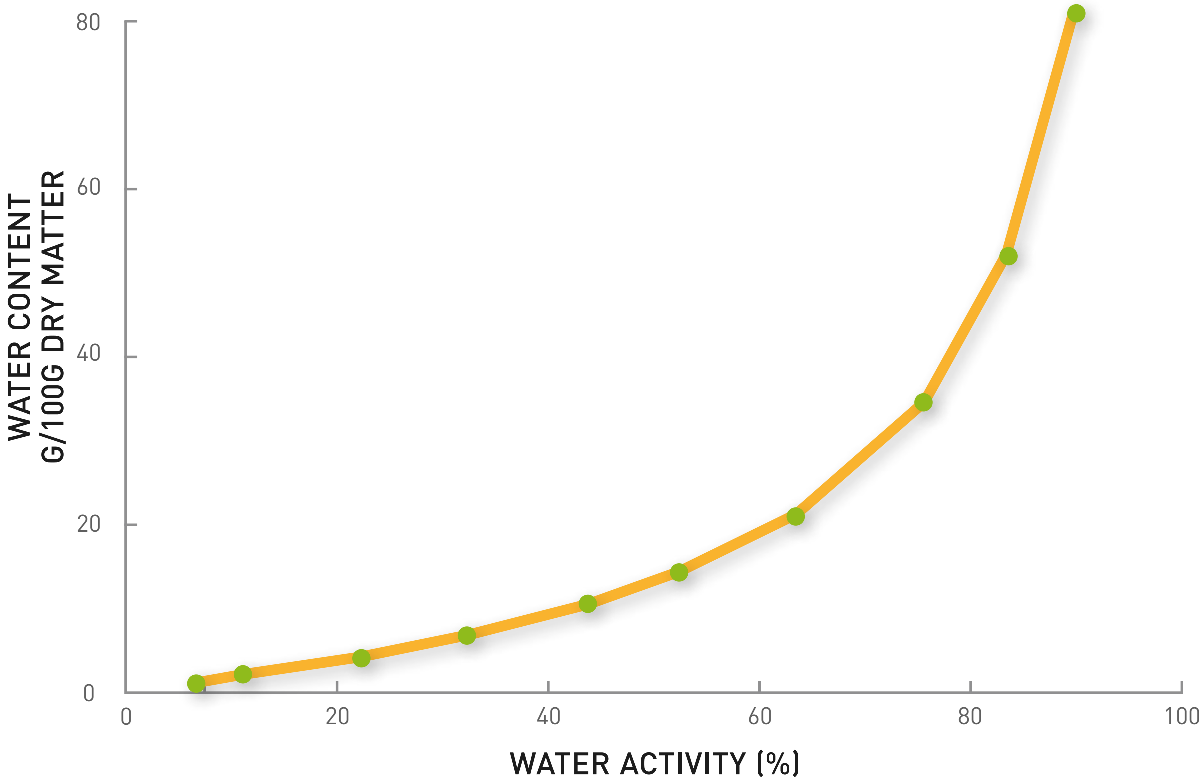
However, where, initially, this drop in aw promotes a decrease in microbial and enzymatic activity, **it can then promote other reactions** such as the oxidation of lipids or even the Maillard reaction[37].

In fresh mango, for example, **more than half of the water can be considered free**. The water content for effective preservation (**aw target value close to 0.6**) is around 14 g of water per 100 g of dried mango (Rivier *et al.*, 2009). The relationship between moisture content and aw for a specific variety and degree of maturity of mango is shown below.

36 Energy must be supplied to a chemical system for the reaction to take place. This energy is thermal in nature.

37 The Maillard reaction is the set of interactions resulting from the initial reaction between a reducing sugar and an amino group. This reaction is of enormous importance in food chemistry. It is mainly responsible for the production of odours, aromas and pigments characteristic of cooked foods (non-enzymatic browning typical of heated products). It can also give rise to carcinogenic compounds and also reduce the nutritional value of foods by breaking down essential amino acids.

Example of a mango desorption isotherm at 30°C. (presented by Rivier *et al.*, 2009)



Source: J. Telis-Romero, M.N. Kohayakawa, JR.V. Silveira, M.A.M. Pedro et A.L. Gabas, "Enthalpy-Entropy compensation based on isotherms of mango", *Ciênc. Tecnol. Aliment.*, Campinas, 25(2), 2005, pp. 297-303.

According to these authors, this curve is given by way of example and any difference in the fruit's composition can modify it, in particular differences in the concentration and composition of sugars (glucose, fructose).

7.1.2. The principle of drying

The principle used when drying fruits and serving to lower water activity is to bring a product with a certain humidity into **contact with a hot air stream that is drier** than the product.

Effective drying means being able to control **three fundamental parameters**.

1. **The capacity of the surrounding air** (also known as entrainment air) to **absorb the water vapour** released by the product. This capacity depends on the percentage of water vapour already contained in the air before it enters the dryer and also the temperature to which it has been heated. The **relative humidity of the air** is an important parameter for drying. It is the relationship between the water vapour pressure in the air and the maximum capacity that the air can hold under these conditions (pressure, temperature).

   In other words, for the drying process to take place, the relative humidity of the air must therefore be lower than the water activity at the surface of the product. Sometimes the atmospheric air is too humid to perform drying, mainly during the rainy season when the air is already loaded with humidity.

This is one of the reasons that the air needs to be heated for the drying process to take place.

Heating the air **will increase the maximum amount of water vapour the air can hold**; conversely, lowering the temperature will lower this amount. This difference explains why, at the same relative humidity or the same water saturation level, cold air is drier than warm air.

2. **The thermal energy provided** heats the product and causes the migration of water to the surface and its transformation into water vapour. During drying, when the air is heated, it lowers the relative humidity and increases the evaporative power of the air by increasing the amount of water that the air can collect before reaching saturation.

   The difference in pressure gradient between the product and the air will induce a transfer of water (or mass transfer) from the product to the air, which is drier.

   For this to take place, however, this mass transfer requires an input of energy in the form of a heat transfer. This heat input can come from different sources (solar or electromagnetic radiation, heated surfaces, convection from a fluid).

   When the hot air passes over the fruits placed in the dryer, the latter will transmit part of its heat to the product, thereby resulting in a heat transfer from the hot air to the product, which in turn results in a mass transfer from the product to the air. This mass transfer is actually the transfer of water from the product to the drier air.

   The product therefore becomes increasingly drier and lighter during drying. The process that takes place in the driers is called "entrainment drying", with the water evaporating without boiling.

   The **transfer of water from the product to the air takes place at the periphery of the product**. There is therefore an internal transfer of water, from the middle of the product to the periphery. However, the further along the drying process, the greater the thickness of the dry area at the periphery. **It will therefore take more and more time for the water to reach the periphery** (drying speed therefore decreases over time).

   At the start of drying, when water is available at the periphery, the supply of heat by the air available for heat transfer is the limiting factor in drying. But at the end of drying, the migration time from the centre of the product becomes the limiting factor.

3. **The speed of the air at the level of the product must be high, specifically at the start of drying,** (up to a certain limit) so as to accelerate the entrainment of water vapour. It must be possible to dry the product sufficiently quickly (to prevent putrefaction), but not too quickly (a crust may then form on the surface) or at too high a temperature (the product denatures and turns black).

   In many dryer models, no back-up ventilation system is added to the dryer. The air therefore flows naturally over the products; a feature known as "**natural convection**".

To improve the heat transfer from the air to the product and the water transfer from the product to the air, it may be more beneficial **to use a system that increases the air flow speed (fan).**

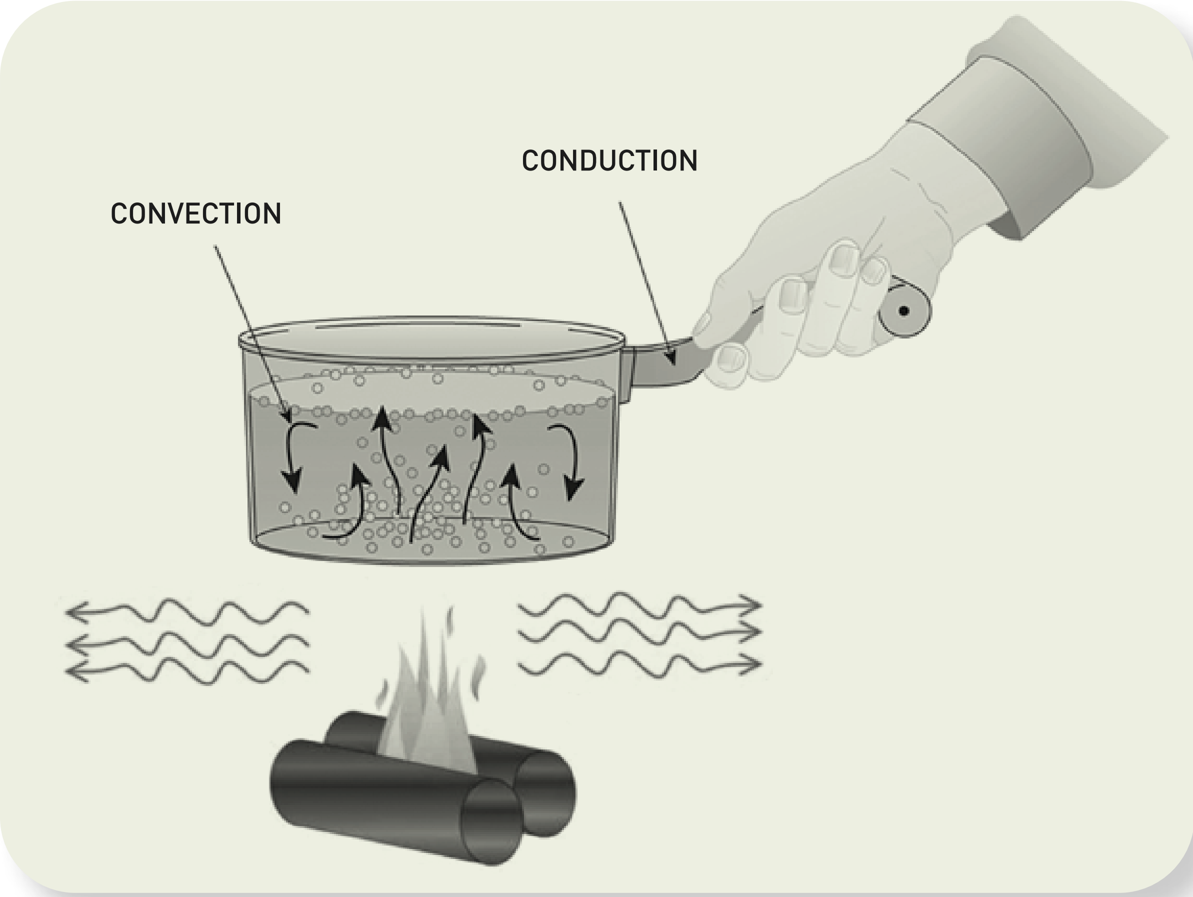
In fact, when this process is not in place, the flow is laminar: there is no mixing effect. Exchanges therefore only take place via the boundary layer **by conduction.**

However, when the flow speed is increased, for example, by using a fan, the flow becomes turbulent and the exchange mechanisms are caused by **convection.** As heat transfers carried out by convection are more efficient than by conduction, the fan makes it possible to homogenise the air flows in the dryer, and consequently to increase the efficiency and the homogeneity of this dryer.

CONDUCTION AND CONVECTION

Thermal conduction, also called diffusion, occurs in a body or between two bodies in contact.

Thermal convection depends on the movement of mass from one region to another. The convection of heat occurs when the bulk flow of a fluid (gas or liquid) carries heat along with the material flow in the fluid.



7.1.3. Factors that influence the drying process

Drying will be influenced by the amount of water available in the fruit, *i.e.* by **its basic aw.** Drying will therefore take longer and longer as the drying progresses, the free water is evaporated and an attempt is made to remove the bound water. As a reminder, to break the bonds binding the water, it is necessary to bring more energy to these bonds. The amount of energy required for drying therefore becomes increasingly important if we try to dry the products more vigorously.

The drying pattern can be divided into **four phases**:

- **phase 0**: temperature rise of the product to the surface evaporation temperature;
- **phase 1**: evaporation of free water at the surface at constant speed, migration of water from the centre of the product;
- **phase 2**: slower drying, more difficult migration of water from the centre, because the periphery is drier;
- **phase 3**: often coupled with phase 2, evaporation of bound water.

During phases 2 and 3, a rise in temperature of the product is observed: this can cause the appearance of the phenomenon of non-enzymatic browning. It is therefore essential not to overheat the products during these phases. **This is why the temperature must be lowered during drying.** Indeed, when the temperature rises too high, the reducing sugars and the amino acids they contain (e.g. lysine) react (Maillard reaction), which leads to the formation of brown-black compounds (melanoidins). and the development of aromatic substances. Heating can therefore have an impact on the colour, smell and taste of the product[38].

Aside from the three parameters we have discussed, in order to carry out the drying operation effectively, it is also necessary **to take into account the characteristics of the individual fresh product** (for example, the difference between an oily fish and a leaf vegetable), and to decide on those to be achieved in the final product (texture, colour, specific taste).

Controlling a drying process effectively also means **controlling the quality of fresh and dry products, upstream and downstream of the drying process itself** (supply of fresh products, sorting of these products, trimming, pretreatments, downstream storage, control of the dry product, possible incorporation of flavouring and preservative agents, packing, upstream storage, distribution chain, etc.).

38 This formation of coloured and aromatic compounds can be favorable for certain foods such as bread, coffee or cocoa. However, for the production of dried fruits, these compounds are undesirable and it is necessary to avoid the occurrence of the Maillard reaction.

7.1.4. Enzymatic degradation caused by drying

Lowering water activity to between 0.60 and 0.65 inhibits microbial activity, but is not enough to suppress the activity of enzymes.

To recall, enzymes are **proteins naturally present** in every living being. Certain enzymes can have a degrading effect on certain molecules present in the product. If the enzymes are left intact in the product, a phenomenon of enzymatic degradation may appear, which is the **organoleptic deterioration of the product** (mainly taste and colour) due to the activity of the enzymes present and their effects on product components.

To suppress this enzymatic activity, the most effective treatment is **treatment by sulphuring with sulphur dioxide** (principles and disadvantages presented in another chapter).

Other methods can be used to stop or slow down the enzymatic degradation process.

- **Blanching** is the process of soaking fruit in hot water for a few minutes. This process also allows faster drying of the fruits. However, fruits are not always suitable for blanching, as this makes them less easy to handle, and leads to losses of water-soluble, nutritional and aromatic compounds (considerably more prevalent in fruits than in vegetables).
- **Acidification**, often performed using citric acid (which can come from lemon juice), is less effective when compared to sulphuring or blanching because it slows the browning effect, rather than preventing it fully. This process can also be used in addition to blanching.

7.2. TYPES OF PRODUCTS

7.2.1. Product appearance

In ACP countries, dried fruit largely dominates the market compared to vegetables (whereas in Turkey and the Middle East there is a large traditional market for dried vegetables). These products are mainly distinguished **by the cutting undergone** before drying. We can therefore find dried products (especially fruits):

- whole,
- in slices,
- in pieces.

The choice between these different formats will mainly depend on the type of fruit processed.

It should be noted that in some countries, **compotes**[39]**, or fruit or vegetable purées are also dried and referred to as "leathers".** A homogeneous liquid purée (with or without the addition of sugar or honey) is spread out on a tray covered with Paraflexx (Teflon) sheets, dehydrated and dried in the form of a flattened cake. This is then cut into strips or pieces. The final product has a thickness and consistency similar to that of leather straps (hence the name fruit leather).

Example of "fruit leather"
(purée of strawberries, dehydrated
and cut into strips which are rolled)

Dried pineapple slices

39 A "compote" refers to fruits that have been quartered or crushed, then cooked with water and sugar. When the fruits are simply ground using a blender, without being cooked, the output is referred to as a "purée". In addition to fruit, "ketchup" (most often made from tomatoes) also contains vinegar, sugar, salt, chilli, cloves and even cinnamon (for the American market) or onions and celery (for the Mediterranean market); other spices are also frequently added to ketchup.

7.2.2. Sulphuring

One of the means used to differentiate the products is also based on the pre-drying process, and in particular on the presence or absence of a **sulphuring process**. This treatment can be applied in different ways, by immersion or by exposure to SO_2 vapours (solid sulphur is burned and the fumes are deposited on the fruit).

This stage of the process will have a significant effect on the shelf life of the product. Products that have not undergone any treatment can be stored for three months before showing any deterioration in taste or colour. To achieve longer storage times, it is necessary to introduce an additional preservation process (e.g. dried products, such as tomatoes preserved in oil).

In the case of dried products, the **main purpose** of sulphuring is to **preserve the colour** of the fruit by **preventing enzymatic browning**, to **preserve the flavour** by improving the retention of aromatic compounds, and to **avoid nutritional losses**. However, because sulphuring also plays a **role in preservation** against micro-organisms, a relatively high water content can be tolerated in dried products (e.g. slices or pieces of dried pineapple). These products therefore present as soft fruits or fruits with a high water content.

The table below shows the differentiation of the products according to manufacturing process (with and without sulphuring) which notably **impacts the water content tolerated in the dried products**.

	Maximum water content without sulphuring	Maximum water content with sulphuring
Mangoes	15%	15 to 35%
Apricots	20%	25%
Papayas	18%	18 to 25%
Pineapples	20%	20 to 44%

However, sulphuring leaves **sulphite residues (SO_3^{2-}) on and in the product, which are problematic** because they are classified as an allergen. In reality, sulphites don't cause true allergic reactions, however they are included in the list of priority food allergens because of the allergy-like symptoms that can occur in people who are sensitive to them. For this reason, in Europe, the declaration of the presence of sulphites (E220 to E228) in food is obligatory when their concentration reaches 10 mg/kg[40].

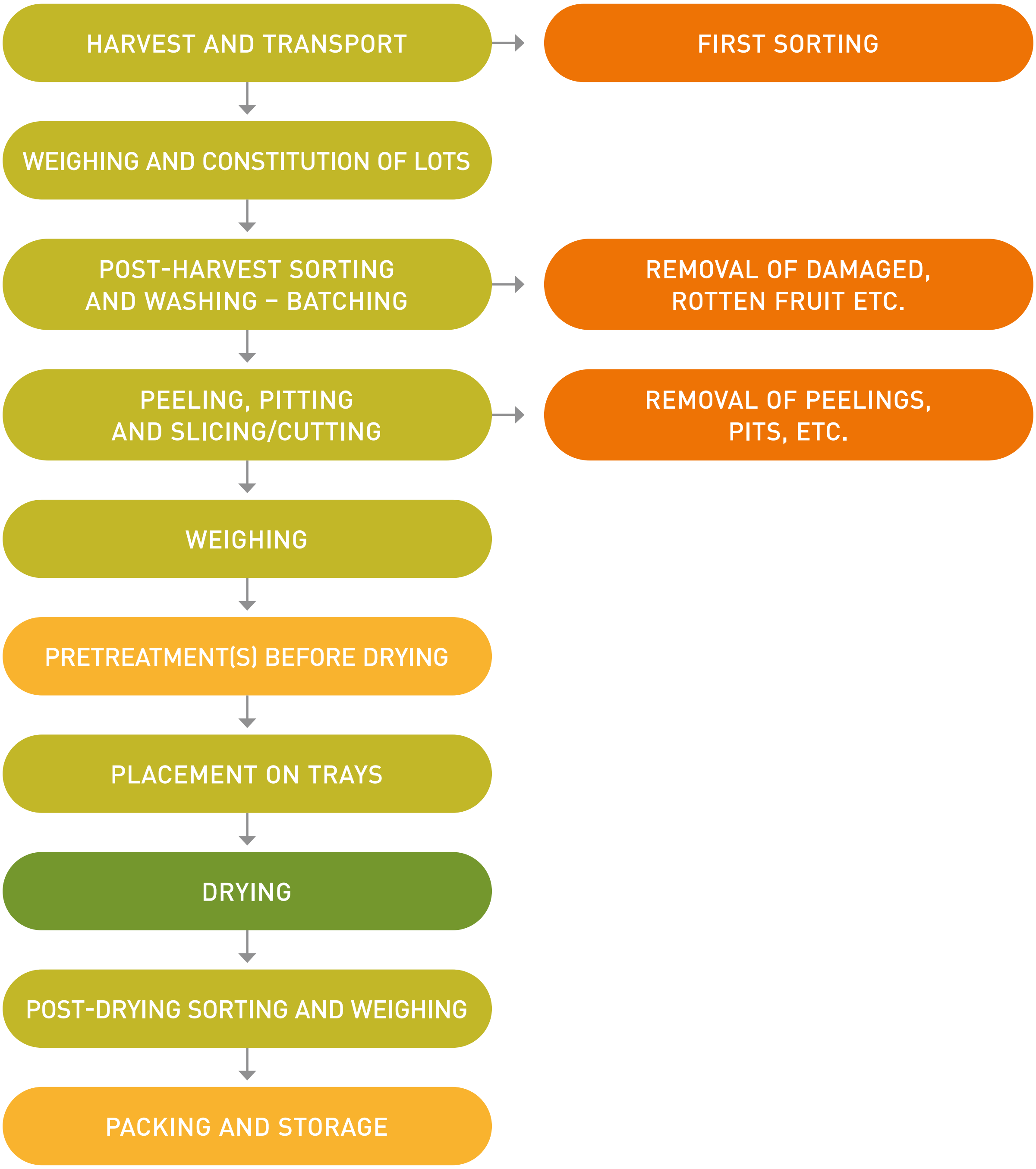
40 Sulphite concentrations in raisins, apricots, prunes, bananas, apples or dried dates can reach 500 to 1000 milligrams per kilogram.

7.3. FLOW DIAGRAM OF THE GENERIC PREPARATION OF DRIEDPRODUCTS

Although, for each type of product, specific or additional steps are justified and necessary in the process (e.g. ripening of the fruits, pitting, etc.), it is nevertheless possible to present a generic process for the manufacture of various types of dried fruits and vegetables. Additional operations are also proposed to treat, for example, fruits removed during sorting or by-products (e.g. peelings, pits), or simply to treat the waste water used to wash the fruit.

The important points to note at the main stages will be briefly recalled.

Flow diagram of the generic process



7.3.1. Harvest stage

Special attention should be paid to the fruit from the harvest stage in order to achieve a high-quality product. It is during the harvest period (which varies depending on variety) that the fruit picking takes place. Regardless of the product and where it comes from, the picking stage is hugely important. Indeed, this takes place when the fruit is at the ideal level of ripeness. When harvesting, it is therefore important to **select fruits carefully** in order to choose fruits **at their stage of optimum maturity, when the sugar and flavour levels are at their peak**, *i.e.* when their nutritional and taste properties are optimal. For example, in the case of mangoes, you must avoid picking fruits that are too green as these have not yet reached maturity. The person in charge of harvesting operations will need to measure the degree of maturity of the fruit (to recall, the colour of the fruit is not necessarily an objective criterion, because it also depends on the location of the fruit among the branches and therefore the amount of sunshine received).). The same is true for figs, which should also be harvested very ripe. This is why an initial sorting stage takes place on site, at the time of harvest and before their transport (preferably in crates) to the processing site.

7.3.1.1. Example of criteria for selecting mangoes for drying

Mangoes to be purchased for drying should be sorted at the edge of the field after picking. Only ripe mangoes should be used. Very ripe, green or damaged mangoes should be discarded. When ripe, the fruits are full with a smooth, healthy and shiny skin, the stem well embedded in the base of the fruit. The colouring of the flesh varies from light yellow to dark yellow depending on the variety. The **criteria for assessing the maturity** of a mango are as follows (with variations depending on the variety):

M I: corresponds to the unripe green fruit

M II: corresponds to the onset of maturity

M III: stage of development of maturity that shows a light yellow colour of the flesh

M IV: the colour of the fruit is yellow-orange

M IV: the colour of the flesh is yellow-orange

M VI: corresponds to ripe fruits

Source: "Le Guide du sécheur de la mangue" (Guide to drying mangoes) (version 3), PAFASP, Burkina Faso

According to the PAFASP guide, if mangoes are to be stored for the production of dried fruits for more than a week, it is advisable to buy mangoes at stages M III to M V. The ripeness for drying corresponds to stage M VI for the Amélie variety[41] and MV and M VI for the Brooks variety (optimum quality). At these stages, mango is safe to eat. It is also at these stages that is recommended to dry the fruits.

The **training of harvest managers** (and their experience) and the awareness of the harvesters themselves are therefore essential for the selection and picking of fruits, in particular to minimise the damage caused to the fruits. Indeed, when fruit is handled and stored in boxes during the harvest it can easily be damaged. **This trauma** (cuts and perforations) enables bacteria and fungi to enter the fruit and develop there, causing the appearance of the putrefaction phenomenon or of brownish spots on the dried fruit.

THE MANGO IS A PARTICULARLY DELICATE FRUIT.

As the mango is a slightly acidic fruit (pH 4.5), any injury to the skin is quickly colonised by yeast and mould causing a change in taste due to fermentation. The presence of too much yeast and mould can also mean that products are non-compliant. During impact, enzymes are released in the cells, causing rapid spoilage of the fruit (change in colour and texture).

41 In this variety, at this stage, small shiny balls of sap should be visible on the skin of the fruit.

7.3.1.2. Generic criteria for selecting fruits for drying

Although it is impossible to generalise, each fruit having its own optimal acidity, ripening and texture for harvesting, a few generic criteria remain that allow us to form an idea using observations and measurements.

Maturity index	Observations
Colour of the epidermis	Usually, the picking is done by determining the changes in skin colour.
Firmness of the flesh	Firmness can also be used as an index of maturity for some varieties.
Measurement of sugars	The sugar level is measured using a refractometer.
Acidity measurement	Determining the acidity of the fruit can give an indication of maturity.
Starch measurement	The starch content in a fruit is transformed into sugar during ripening. The harvest date is considered to correspond to the disappearance of the starch from the fruit.

7.3.2. Post-harvest sorting, lot preparation and washing

7.3.2.1. Receipt and sorting of products

Lots are received following transport from the field or orchard. A delivery note containing information on the quantity, variety and origin of the product will ensure the traceability of the lots. The use of crates not only decreases losses caused by crushing and impact, it also facilitates unloading, storage in the drying unit and lot identification. Crates are also weighed.

As soon as the products arrive, a second visual and tactile sorting is carried out, according to the colour and firmness (signs of maturity)[42], most often at the same time as the inspection aimed at eliminating foreign matter and fruit in poor condition. It is important to remove any that show signs of putrefaction, trauma, etc. Indeed, damaged or even rotten fruit can cause visual or taste defects in the final product. However, it is also important for health reasons to carry out a second sorting of the harvested fruits, because certain types of mould, which would develop during storage (necessary for ripening or to extend the production period), may be responsible for the production of mycotoxins.

Any fruits discarded during this sorting process may then be used in different ways depending on the type of fruit in question and possibly the causes of their removal (for cattle feed only if they do not present a health risk, composting, anaerobic digestion, destruction, etc.).

42 A taste control is sometimes also carried out. In the case of mangoes, it helps to appreciate the flavour of the flesh. The flesh of the Amélie variety is tart while that of the Brooks variety is sweet.

From the point of receipt of the fruits, **it is also very important to work in good hygienic conditions** (cleanliness and disinfection of the premises; regular washing of floors; personal hygiene; cleaning of crates; waste management; etc.).

7.3.2.2. Constitution of lots for drying (batching)

In order to optimise the subsequent stages and obtain **uniform drying**, it is similarly of interest to sort, calibrate and **create homogeneous lots**. This will involve grouping fruits **of the same size and degree of maturity**, etc. (e.g. separate overripe, ripe and unripe fruits; create batches of mangoes from the same site and at the same stage of maturity). In the case of mangoes, the fruits that are insufficiently ripe (e.g. maturity criteria M III, M IV and MV) will be stored separately following a simple wiping, in a well ventilated room (to avoid the accumulation of volatile compounds being emitted in the room), to give them time to mature.

This phase is particularly important because it allows:

- uniform drying;
- better control of subsequent treatments: blanching and possibly sulphuring;
- a good valuation of the product (the best lots selling at a higher price);
- the appearance of products free from defects for the consumer.

Grading is carried out manually, on a table, in small plants, or on a roller belt for large volumes.

Following grading, it is possible to use fruits that do not meet the set criteria for other preparations (e.g. jams).

7.3.2.3. Washing

Once sorted, the fruits must be washed, because their surface naturally bears impurities, micro-organisms, insects, etc. Without washing, the knife used in the next step (cutting) can be contaminated from the surface and go on to contaminate the flesh of the fruit and subsequent fruits. Without washing, the hands and clothing of staff will also be contaminated.

Washing the mangoes (source: 'Guide d'exportation de la mangue fraîche du Burkina Faso" (Burkina Faso Fresh Mango Export Guide), PAFASP)

The fruits are therefore first washed with clean water (not necessarily "drinking") to remove the impurities present (dust, soil, etc.), or even to eliminate some residue deposits on the surface. It should be noted that washing using water does not remove the micro-organisms that are already present.

On a domestic level, the most commonly used item remains the washing up bowl. At the artisanal level, a container fitted with muslin cloths makes it easy to collect clean products. In large companies, washing is done in large containers.

To reduce the microbial load on the surface of the products, **they must be washed with bleach** (15 minutes of contact with water prepared at the rate of 4 ml of bleach at approximately 10% active chlorine per 10 litres of water). It will then be necessary to rinse the fruit again, with drinking water, to remove all traces of the bleach[43]. From this point the fruits are considered clean. Necessary measures should be taken to **avoid any recontamination caused by a lack of hygiene** of places or people.

7.3.3. Preparation of products for drying

Prior to the drying process, three operations take place successively: **peeling, trimming and cutting**. These preparatory operations are long and require significant manpower, because they remain manual in the majority of cases.

7.3.3.1. Peeling

Peeling removes the skin (using a knife[44]) from certain vegetables or fruits which slows down the evaporation of water and is not edible. Peeling and possibly pitting depends on the type of fruit. Certain treatments make it possible to facilitate manual peeling: the treatment of vegetables with moist heat (boiling water or steam) makes it possible to detach the skin easily after cooling. One variation is to grill the vegetables over a flame. Old vegetables are much more difficult to peel because their skins wither. This is also why it is of interest to work with fresh products. When peeling, it is important not to remove too much thickness, as some vegetables concentrate their nutrients at the periphery (potatoes). In addition, the material waste is greater. As this operation is manual, the products deteriorate and turn brown while waiting to be peeled. It is therefore desirable to store the vegetables in salted water (20 to 40 g of salt per 1 litre of water), which must be changed regularly to avoid microbial contamination. On the other hand, this soaking improves the texture and facilitates the drying of green vegetables (spinach).

7.3.3.2. Trimming

Trimming, carried out by hand using knives, enables the removal of the inedible parts of the product (e.g. stems, fibres, roots, pits, etc.), as well as damaged or insufficiently ripe areas.

43 Bleach is a chemical that is diluted and sold for household use. It is a mixture of water and sodium hypochlorite. For home use and in many workplaces, it is usually sold with sodium hypochlorite concentrations ranging from 3% to 10%. Bleach is corrosive, which means it can **irritate or burn your skin or eyes**. It can also corrode (destroy) metals. When mixed with other chemicals or cleaners (e.g. ammonia-based products), **it can produce toxic gases** which can damage the lungs or be fatal. Always use caution when using this product, wear goggles, gloves and ventilate the premises.

44 The use of stainless steel knives is essential. Iron knives cause discoloration by **promoting oxidation**.

7.3.3.3. Cutting

According to CIRAD, **cutting** is essential for thick vegetables and fruits (tomatoes, potatoes, mangoes, pineapples) which, without this operation, would dry too slowly and would be exposed to attack by micro-organisms. There are different forms of cutting: into slices, cubes, rings or strips. The same product can come in several forms. For example, dried onions are available in rings or strips. For mangoes, there are several kinds of cuts: the disk cut, the wafer thin cut and the half disk. In fact, the presentation of the product should correspond to local customs and consumer preferences.

However, the shape and size of the pieces influence the drying time. Cutting (sometimes slicing, as in the case of pineapple), where necessary, **defines the final shape of the product** and is **decisive for the drying stage**. Indeed, the type of cut **will determine the possible exchange surface area** between the water in the product and the air, as well as the time necessary to extract the water from the centre of theproduct. This stage therefore determines the drying time of the product. The product will dry faster with a larger exchange surface area and a lower thickness. Thinly-cut products will tend to **dry faster, but also more strongly**, which can make the product too hard (especially on the thinner edges). Thicker products will tend to stay "softer", but will require a much longer drying time. It is therefore important to find a compromise between the two.

CUTTING IS CRUCIAL FOR THE QUALITY OF THE DRIED PRODUCT.

To achieve homogeneous drying, it is important that the different pieces are **cut as homogeneously as possible** (shape and thickness), but it is of equal importance that each individual piece is cut homogeneously to avoid obtaining a product with a thinner part, which will be drier, and a thicker part that is insufficiently dry.

Both peeling and cutting are performed on a table provided for this purpose. The peels and pits fall on to the table and are regularly pushed into waste bins, through two or three holes made in the table. The peeled products are placed in plastic trays for the next operation.

Light fruits (e.g. bananas) turn brown very quickly during this operation. To limit this change in colour, it is advisable to **cut them at the last minute** and to keep the pieces **in clean water with lemon juice** until the next stage, which must take place promptly.

7.3.4. Pretreatments for drying

Treatments include blanching, sulphuring and adding an acid solution, sugar or even a gelling product (e.g. pectin). As explained above, the **main objective** of this treatment stage prior to drying is to destroy or stop the enzymes responsible for enzymatic degradation. While these treatments are "optional", without the use of pretreatments before drying, finished products will have a shorter shelf life and will need to have a lower water content.

7.3.4.1. Blanching

This treatment is optional, but recommended. It is used to **improve the quality** of finished products and to **facilitate drying**. Blanching involves soaking the fruit in boiling water so that the fruit reaches a temperature of 80 to 100°C for a few minutes (the time varies depending on the product and the size of the cut pieces). For more delicate fruits, blanching can be done by sprinkling them with a trickle of hot water. Not all vegetables can undergo this treatment. This is the case with onions and garlic, which lose their pungent flavour when heated. For leafy vegetables, this treatment is not necessary.

Comparative advantages of water and steam blanching
(source: P. Dudez, *Le séchage solaire à petite échelle des fruits et légumes – Expériences et procédés* (Small-scale solar drying of fruits and vegetables - Experiments and processes), GRET and CIRAD)

	With water	With steam
Advantages	Basic equipment required and low purchase cost Easy to process large quantities. It is easy to find large vats Faster than steam blanching	Water can be reused 5 to 6 times Uses considerably less water Prevents the loss of soluble nutrients
Disadvantages	Significant loss of soluble nutrients High water consumption, even if it can be reused several times	Cleaning wire baskets is difficult Difficult to achieve uniform treatment Cannot process large quantities because the product layers must be thin, which requires a lot of space

Blanching serves several purposes.

- Destroys a large amount of the micro-organisms present in the product. Take care to follow appropriate hygiene requirements, as new contaminations can occur after blanching.
- Makes the cells more permeable, to facilitate the removal of water during drying.
- Slows down the degradation of food, in particular colour and nutritional value (vitamin C and provitamin A, in particular).
- Improves the texture of the product upon rehydration.

Several precautions must be taken during this operation if it is performed (same source).

- When the vegetables are placed in the pot, the water cools. It is then necessary to wait for the water to boil again before timing the blanching period.
- Ensure the homogeneity of the lots. If different sizes are present, the smaller ones will be over boiled, while the larger ones will not have undergone adequate treatment. The quality of the product will be irregular.
- Do not excessively prolong the soaking time, otherwise the vegetable loses its consistency and vitamins and soaks up water.
- Once the blanching is complete, cool quickly in cold water so as not to overcook the vegetables, then drain them.
- The easiest way to blanch is to use a muslin cloth or wire basket that is dipped into a pot. For larger quantities, a square of gauze can be used by tying the corners together and making a loop. To handle the gauze, a stick can be passed through the loop

It is known that **adding citric acid or even lemon juice** (antioxidants) to the blanching solution makes it possible to better preserve the colour of the treated product.

Water and steam blanching (source: P. Dudez, *Le séchage solaire à petite échelle des fruits et légumes – Expériences et procédés* (Small-scale solar drying of fruits and vegetables - Experiments and processes), GRET and CIRAD)

If the rise in temperature destroys the enzymes responsible for enzymatic degradation, it will also have an effect on the cells of the fruit by causing the cell walls to rupture, which in turn makes the fruits more difficult to handle. This drawback is one of the main reasons why sulphuring is preferred over blanching.

7.3.4.2. Sulphuring

Sulphuring is the most commonly encountered pretreatment for drying fruits and vegetables, because it is the most effective. Its principle and interest has been explained above. Pretreatment by sulphuring makes it possible to obtain good results both for the preservation of the organoleptic and the nutritional qualities of the product. However, this pretreatment can lead to specific losses of sugars and vitamin C and even to the development of undesirable tastes if sulphuring is applied in excess.

This treatment can be carried out in two ways.

- **By immersion** (wet sulphuring): the fruits are directly immersed in a solution of **potassium metabisulphite** ($K_2S_2O_5$), the most commonly used product. This compound, which is in the form of a white crystallized powder, is a preservative that must be indicated on the label as an additive (code E224). Fruits are kept in the solution for five to ten minutes and are not dried until 12 hours later to allow the sulphites to distribute themselves inside the fruit.
- **By fumigation** (dry sulphuring): this is carried out in a closed room, often after placing on trays, using **sulphur vapours** (sulphur dioxide or SO_2, the presence of which must also be indicated on the label: code E220).

Sulphurisation lasts between 2 and 3 hours, or sometimes longer. Fumigation is more economical, but it is more complicated to estimate the amount of sulphites actually absorbed by the product. The amount of sulphur to be added depends on the drying method used (solar or non-solar).[45]

As sulphurised vapours are harmful to health, it is necessary to take measures to protect workers and people in the vicinity of the treatment site.

Sulphites are also among the major food allergens. They can therefore have a significant negative effect on consumer health and their presence must be indicated on the product label if the concentration is greater than 10 mg/kg.

45 For the fumigation of fruits dried by non-solar processes, it is generally considered that 300 g of sulphur should be added per 100 kg of fruit, for a maximum of 2 to 3 hours. Almost twice this amount should be added for solar dryers.

7.3.4.3. Addition of acid, sugar or pectin

The addition of citric acid or lemon juice slows down the onset of browning, however excess amounts should be avoided as this can degrade vitamin C and fructose. Unlike sulphuring or blanching, acidification does not suppress the activity of enzymes in the long term; their activity will only be slowed.

Adding sugar reduces the available water and can improve colour, texture and taste. However the addition of sugar is complicated to achieve. It requires specific know-how and equipment.

Adding 0.5 to 0.75% of pectin can improve texture (e.g. for dried mango), although it also alters the flavour of the product.

7.3.5. Placement on trays

Once ready for drying, the fruits are placed on clean, dry trays. This is an **essential stage** to achieve a smooth and optimised fruit drying process.

The trays are, for example, composed of wooden frames woven with plastic cord measuring 0.7 m x 1.2 m (0.84 m^2). A mosquito net is stretched over the frame on which the mango slices are spread.

The pieces or slices should not be touching or overlapping in order to allow air to circulate through the trays. The quantity of fruit on the trays must be maximal, in order to avoid lowering the productivity of the process. However, in addition, it is absolutely necessary to prevent the slices or pieces from overlapping. When one part rests on another, there is a great risk of this resulting in an insufficiently dried area. This area with significant water activity is then at risk of spoilage and/or the multiplication of potentially dangerous micro-organisms. To counteract this effect, the drying time can be increased. This may not only overdry other parts of the product, but also affect productivity.

7.3.6. Drying

Once placed on the trays, the fruits can be dried. The loaded trays are introduced into the dryer for the process of removing water from the product. The drying process takes place over a period of 18 to 24 hours, according to a well-defined system. The aim is to reach an aw value of close to 0.6.

The principle of drying has already been described. There are different **types and models of dryers** which are presented below. The most expensive item is the **energy consumed** to extract the water from the product (this represents 15 to 20% of the cost price). It is therefore important to choose a type of dryer with varying energy efficiency.

7.3.7. Packing

After drying, the products are immediately unloaded and the pieces are quickly peeled off the mesh (within an hour) to prevent the fruit from sticking to the fabric. They are put to cool and a further **sorting stage is then carried out**. Differences between fruits, including those which may appear during the pretreatment or treatment stages, mean that the products obtained after drying are not all of the same quality. By separating the finished products into different "classes", we can determine the purpose of the products and choose the type of packing suited to the target market.

Products that are **insufficiently dry** will again be returned to the dryer for further drying.

For products for which the **drying process is complete**, sorting will make it possible to distinguish three classes of finished products.

- **First choice or superior quality**: often intended for export and packaged in small formats (bags of 100 g to 5 kg). The product must have a colour close to the fresh product with no browning, a preserved taste and a homogeneous cut. For mangoes, the standard shape is 6 to 8cm x 3 to 5 cm and a thickness of 2 to 4 mm. The value of these products is more than double that of the other two classes.
- **Second choice**: often of the same quality as the first choice, but with problems with the size or shape of the pieces. These are intended for the local market, often packaged in bulk and on demand.
- **Third choice**: fruit with obvious defects, overdried fruit, brown fruit from overdrying, etc. These are intended for the local market, often packaged in bulk and packaged on demand.

To achieve a quality product, suitable packing is essential. In fact, packing has an impact on the organoleptic, safety and nutritional quality of the product. It is therefore essential to choose the right packing for dried fruits. The latter must **prevent oxidation reactions, the absorption of humidity and keep the products protected from light**.

For **primary packing**, the dried products are packaged in larger or smaller portions (100 g, 500 g, 1 kg, etc.), often in polyethylene (PE) packaging. However a bilayer bag (polyethylene/polyamide) is recommended because it prevents the passage of moisture and odours.

Cartons form the **secondary packing**. These allow the primary packaging to be grouped together and protect the primary packaging as well as the product from the external environment, mechanical shocks, pests, dust, and possibly light. They must therefore be rigid. The size and number of primary-packaged items each carton must contain can be defined by the customer.

Tertiary packing is the placement of secondary packaging in pallets or containers, therefore facilitating handling and transport.

Bags and boxes are labelled manually. The contents of the labels can be supplied by the customer, however this must be in mutual agreement with the exporter. The operator should avoid overloading the label and making it dirty. The writing must be visible and legible. The label must make it possible to know:

- the name of the product,
- the date of manufacture or expiry date (BB),
- the country of origin,
- the weight of the product,
- the product ingredients,
- the name and address of the producer (the manufacturer),
- the registration code of the production lot (lot number).

Full cartons are then stored on pallets in a cool room (temperature less than or equal to 25°C), in the absence of bright and ventilated light, and protected from moisture before shipment. The storage room must be impervious to insects, pests and any other parasite likely to contaminate the product, as well as regularly dusted, cleaned and disinfected.

After several months of storage, mangoes can lose their colour. They fade with a tendency to brown. This can be furthered by the storage conditions (high temperature and humidity, very bright light, etc.). Therefore, quality control of each lot is necessary before shipping.

7.3.8. Quality assessment criteria

The standards to be observed during the control generally depend on these specifications which, in addition to organoleptic quality and safety, may also require certain commercial criteria to be followed.

7.3.8.1. Packing controls

For each lot, we systematically check:

- the quality of the packaging (type of bag, cleanliness, seal, absence of holes, absence of foreign bodies, air volume);
- labelling, if it has already been completed (accuracy of data, cleanliness, location and position of the label, gluing);
- the quality of the product (size of the pieces, degree of dryness, consistency and degree of agglomeration, colour);
- the weight;
- the control of closed bags is supplemented by the additional control of a sample of bags which are opened to check the homogeneity of the content.

7.3.8.2. Microbiological stability of the dry product

To ensure efficient preservation, it is necessary that the different pieces of mangoes and the different areas of each piece have sufficiently low water activity: a product humidity which gives it stability over time. Furthermore, the conditions to which the product is subjected during drying must limit the contribution of exogenous micro-organisms and the growth of those present on the surface. To achieve this, the drying period during which the surface of the products is saturated with water must be particularly well controlled.

A sample of, for example,100 g per 100 kg is taken for physicochemical (pH; water activity aw; residual humidity level; possible search for residues of pesticides and mycotoxins) and microbiological analysis (indicators of general hygiene; faecal contamination and spoilage).

7.3.8.3. Organoleptic quality of the products

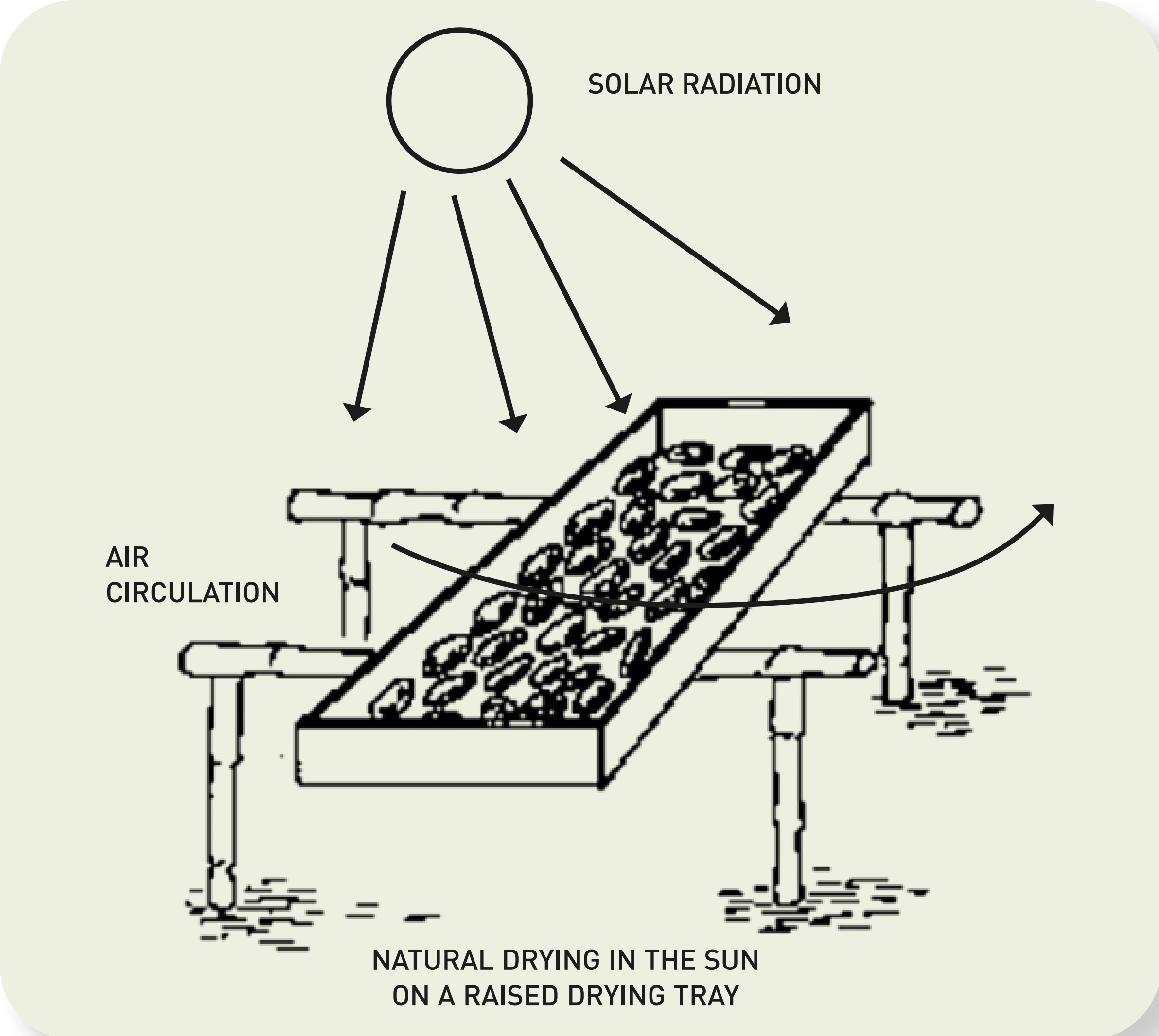
Changes in appearance and aromas may take place during, or be caused directly by, the drying process: enzymatic reactions at the start of drying and non-enzymatic browning reactions (Maillard reaction) at the end of drying. The organoleptic properties depend on the variety. For example, the table below shows those for dried mango.

Organoleptic properties		Physicochemical properties	
Amélie	Brooks	Amélie	Brooks
Taste: sweet, slightly tart	Taste: sweet, sugary	Sugar: 76 - 78%	Sugar: 78 - 82%
Colour: light orange	Colour: orange-yellow	Humidity: 12 -18%	
Consistency: soft dried	Consistency: dried, soft and more or less moist or crunchy.	Residual water: 0.55 - 0.65 aw at 20°C	
Smell: fruity, typically mango		Acidity: 2.5 - 3%	
		pH: 3 - 4	
		Fibre: 2 - 3%	

Source: "Guide d'exportation de la mangue fraîche du Burkina Faso" (Burkina Faso Fresh Mango Export Guide), PAFASP

7.4. CHARACTERISTICS OF DIFFERENT DRYING METHODS

7.4.1. Solar dryers



There are different types of solar dryers

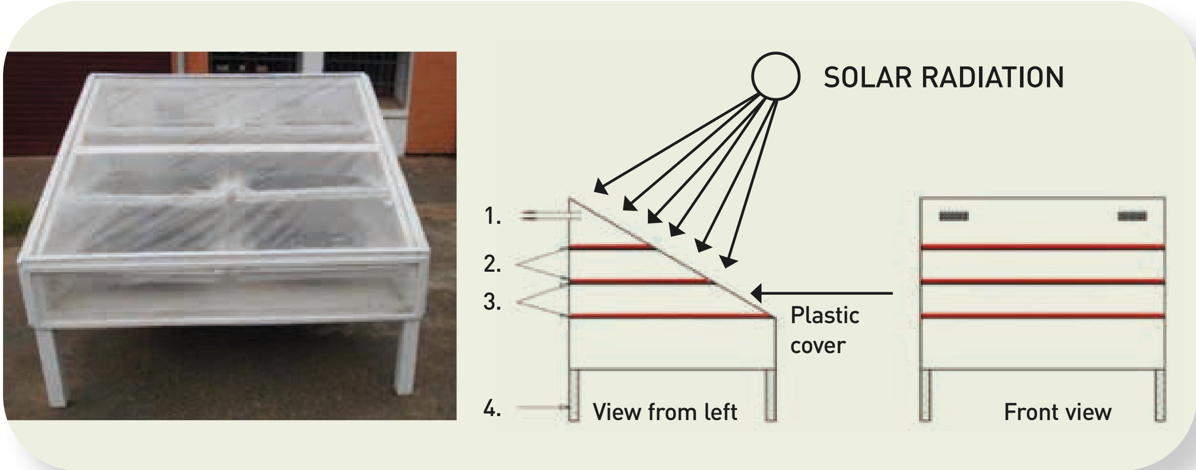
This category of dryer includes **traditional drying**, which consists of placing the fruit on trays, mats or stones and subjecting them directly to solar radiation.

This technique can be improved quite simply by placing the fruit on elevated trays to promote air circulation.

The investment costs are very low for this kind of dryer and it can be suitable as a small cottage industry. However, these traditional dryers **do not allow any control of the process** in that the drying process depends exclusively on **climatic conditions.**

This type of drying takes a long time, requires labour to turn the fruit regularly, and the products can suffer from a deterioration in quality (organoleptic or nutritional) following direct exposure to the sun. It is also possible to encounter the occurrence of nocturnal re-humidification when the sun is not present, which will tend to considerably lengthen the drying process.

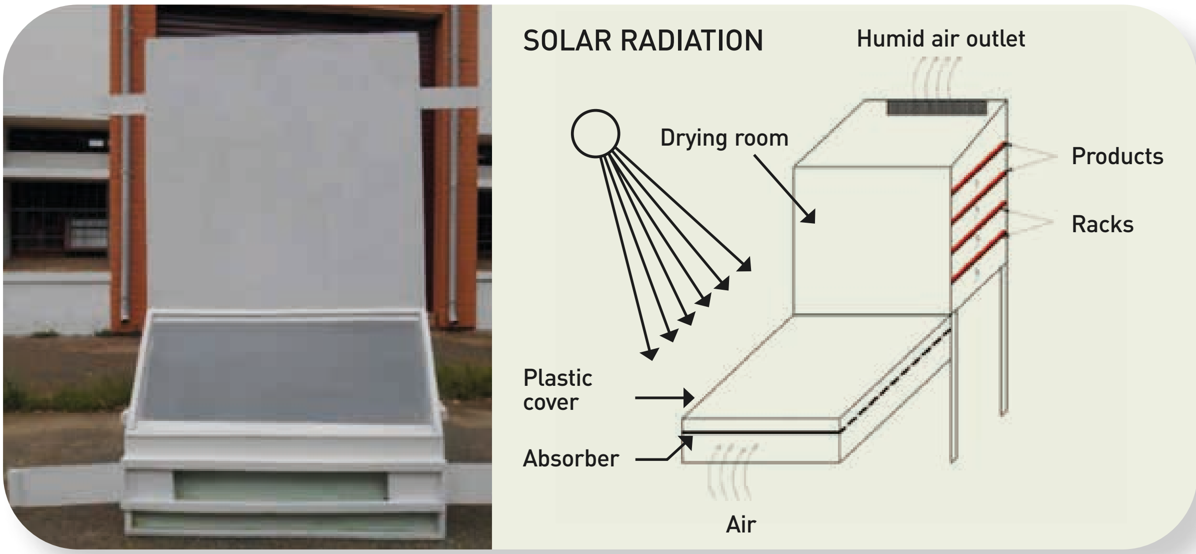
One of the biggest disadvantages of traditional dryers is pests, such as insects, coming into contact with the product. In order to prevent this, it is possible to add a glass or a transparent plastic sheet to close the dryer: this is known as a **direct solar dryer**.



Direct solar dryer (temperature in the dryer: 27 to 50°C)
1. Humid air outlet – 2. Products – 3. Racks – 4. Support

Besides the protection provided by the glass or plastic sheet, a greenhouse effect will develop in the dryer, which increases the internal temperature. However, these models of dryers restrict air circulation, resulting in less efficient drying, and direct exposure to the sun is also responsible for lower product quality.

To avoid direct exposure to solar radiation and therefore a drop in quality, there are also **indirect solar dryer models**. These designs consist of a collector into which air can enter and be heated by the rays of the sun. This air will then rise by natural convection to the drying chamber where the fruits are on trays.



Indirect solar dryer (temperature in the dryer: 24 to 37°C)

Solar dryers benefit from free and renewable energy, which reduces the cost of products. However, the different models of solar dryers all have the disadvantage of being dependent on climatic conditions.

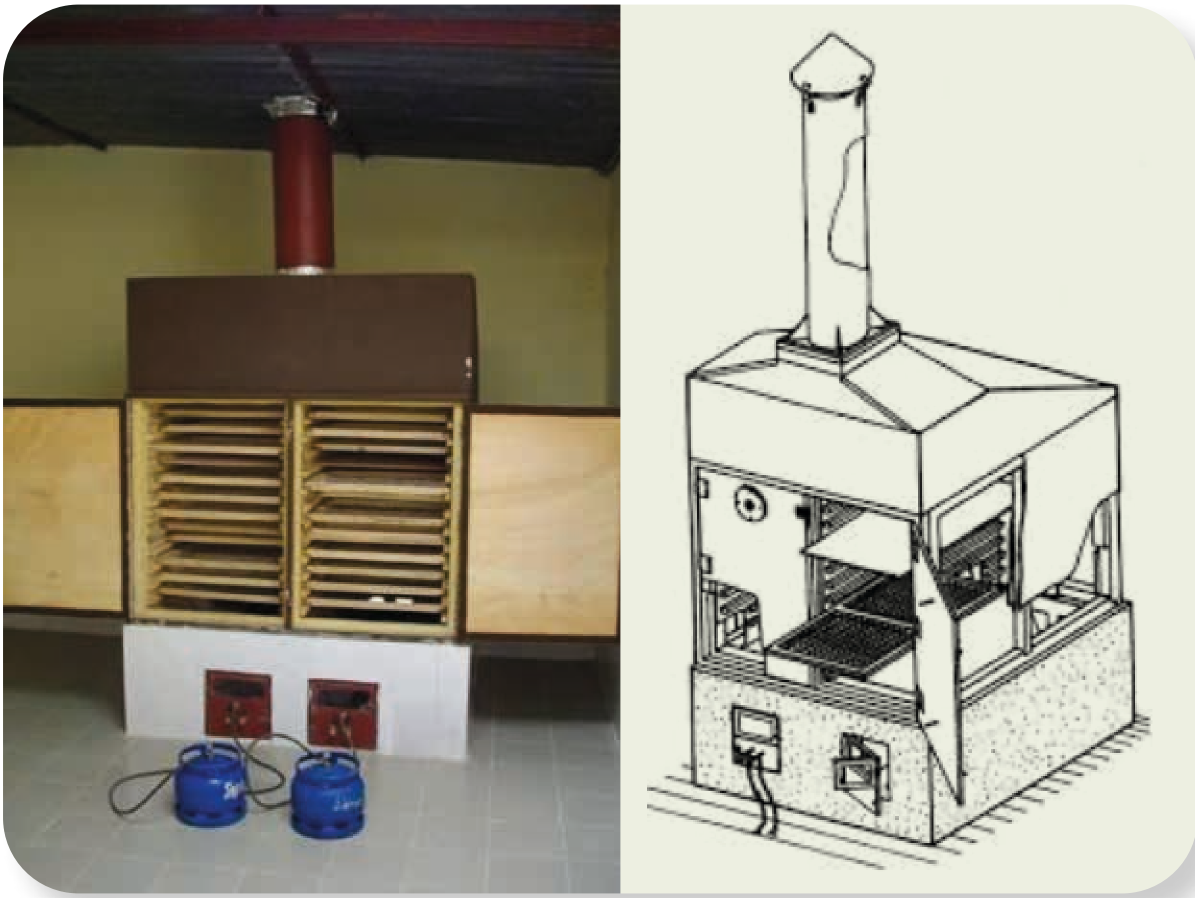
Their effectiveness will therefore depend on the amount of sunlight and the humidity of the air. In the tropics, they can often only be **used outside the rainy season**.

7.4.2. Gas dryers

Gas dryers use gas, **usually butane**, as a source of energy to heat the air and enable drying.

Since these dryers use gas cylinders, precautionary measures must be taken to avoid any risk of explosion or fire. These types of dryers (e.g. CEAS Atesta type dryers - see Appendices) are those most commonly found in West Africa. For the most part, these are natural convection dryers that work with lots.

A burner is used to heat the air which will then pass through the compartment(s) supporting the trays containing the dried fruit. This air will cool and take on moisture on contact with the fruits, it is then evacuated through a chimney.



ATESTA dryer

Hybrid dryers also exist. These models heat the air using gas only or use an air collector identical to that used in solar dryers: **the air is therefore preheated by solar radiation prior to being heated with gas.** The amount of gas required to reach the target temperature is therefore reduced, as are the costs.

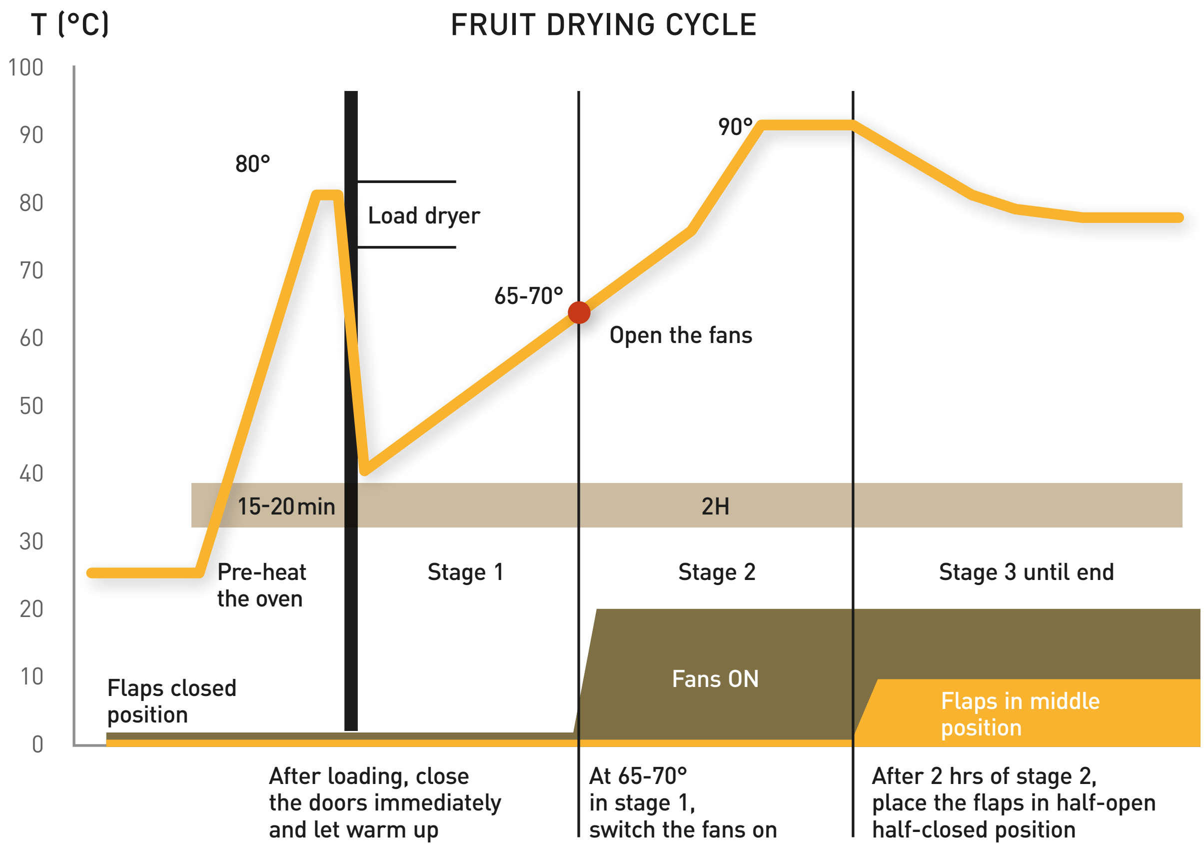
As the air circulation in this type of dryer is from bottom to top, the trays located in the upper part are therefore in contact with cooler and more humid air than the trays located in the lower part.

To avoid excessively large differences in drying between the two areas, **the trays should be rotated periodically** (e.g. every two hours) to allow even drying.

For example, with this type of dryer, the drying of mangoes is carried out over 20 to 24 hours and in two phases. The first phase lasts 10 to 12 hours at 80°C and extracts the free water contained in the fruit. A second phase takes place at a temperature of between 40 and 50°C and allows part of the bound water to be extracted (note that this second phase takes place at a lower temperature to avoid the appearance of non-enzymatic browning or the Maillard reaction).

To improve this drying system, it is possible to switch to a **forced convection system using ventilation.** However, this system will consume more gas and the risk of extinguishing the flame will be greater.

View of an improved ATESTA dryer



Drying cycle in an improved ATESTA dryer

7.4.3. Industrial dryers

Dryers commonly used in industry operate on the same principle as gas dryers. These dryers use the principle of entrainment drying. However, these generally use electricity as a source of energy to heat the air.

Many industrial dryers have also been developed to allow **continuous work**, thereby avoiding the batch effect responsible for a drop in productivity.

Other types of industrial dryers are being developed based on another type of drying process: **drying by boiling**. The principle is to remove the water contained in the product by giving it enough energy to evaporate. Dryers using this drying mechanism **typically operate under vacuum** to help lower the boiling point. A reduced heat input is therefore sufficient as the water contained in the product can evaporate at just 40°C. Other models have also been developed using **microwaves** to allow water to evaporate.

These new drying methods should greatly reduce drying times and obtain uniformly dried products.

7.5. CHECKS TO BE CARRIED OUT DURING THE PROCESS

In this section, **only the hazards that are relevant to the production stages of dried fruit, and the specific features of this type of production, will be discussed.** However, in order to produce safe products, it is of course necessary to work under conditions which comply with Good Hygiene Practices (GHP). The prerequisites to the application of these GHP will therefore not be repeated here (staff hygiene, combating pests, cleaning/disinfection, etc.).

These specific features are of course not an exhaustive list and may vary according to the type of juice or fruit prepared or even according to the type of technique or equipment used.

7.5.1. Pre-harvest risks related to chemical contaminants

Particular attention must be paid to fruits and vegetables during all cultivation operations, **especially with regard to crop protection.** Care should be taken to avoid the presence of chemical contaminants in concentrations that exceed the standards (legally-authorised limit values for: heavy metals present in the soil or supplied by fertilisers; nitrates; pesticide residues, etc.).

If **plant protection products** (such as pesticides) are used on crops prior to harvest (or even post-harvest, such as fungicides on bananas), it is necessary to respect the Good Practices for the use of these products (GAP and GPPP). The type of product, the quantity and the time delay before harvest are fundamental parameters to avoid contamination. Misuse of these products, or the use of a product that is not authorised on the crop, can lead to **exceeding the MRLs in the final product, leading to product non-compliance** (withdrawal/recall), or even - depending on the case - present a real risk to the consumer. The MRLs to be observed are those of harvested fruits, before processing (e.g. upon receipt).

Although washing could eventually remove some residual deposits, in the majority of cases it will have no impact on residue levels. On the contrary, extracting part of the water by dehydration could indirectly artificially increase these concentrations, because the original mass is reduced.

The same applies to the concentration of heavy metals (Cd, Pb, e.g. in dried vegetables), nitrates (in vegetables) or mycotoxins[46] (fruits or vegetables). It is therefore necessary to measure these parameters in the raw material, and **to make the receipt of goods a CCP** in relation to these parameters (check compliance with the limit values).

46 Mycotoxins are toxic chemical compounds produced via the metabolism of different species of fungi such as mould (*Aspergillus*, *Fusarium*, *Penicillium*, etc.), when the different conditions favorable to their growth are met. They are found throughout the food chain, especially in animals that have consumed fodder as well as in products made from contaminated food. Mycotoxins are naturally occurring contaminants of many plant foods, such as grains, fruits and dried fruits. Contamination can occur while the plants are still in the field, but also during the preservation (storage) stage. Mycotoxins are thermostable molecules that are not destroyed by heat treatment. It is therefore important to carry out regular checks to ensure the quality of the products.

7.5.2. Risks during sorting and post-harvest

As described above, special attention must also be paid to the fruits at harvest time, such as through rigorous visual control during the first and second sorting.

The fruits to be dried must be healthy in order to avoid contamination with pathogenic micro-organisms or undesirable metabolites. Therefore, fruit with bruises, damage or areas of mould must be removed during the sorting stage. This should specifically prevent the presence of pathogenic organisms or mycotoxins in the final product, especially when it is stored before processing. Indeed, fungi produce these "toxins" (secondary metabolites) during storage, and more rarely, in the field or orchard for fruits or vegetables (unlike cereals). For dried products, the risk of mycotoxin development should be a more predominant consideration during storage of the finished (dried) products than the period before harvest.

Aside from the health aspect, trauma and other marks present on damaged fruit (e.g. brownish spots) may also be visible on the final product, which may dissatisfy the consumer.

7.5.3. Risks associated with pest control

After the fruit preparation stage (cutting, peeling and pitting), the presence of cut fruit may attract many pests, including flies and some rodents. If no action is taken, insects may land on the fruit and even lay eggs. This is why it is necessary to put in place a **pest prevention and control plan** and measures preventing pests from entering the production premises (e.g. installation of airlock; closing doors with plastic strips; fences; UV lamps; pheromone or glue traps; etc.).

7.5.4. Risks associated with the sulphuring operation

In health terms, it is important to pay special attention to the sulphuring process where it is used as a pretreatment, over and above the risk for the operator, which has been already mentioned. A real health hazard associated with an incorrect dosage of sulphites exists, both from the point of view of under- and overdosing.

If the action of sulphites is insufficient due to underdosing, the risk of the development of potentially pathogenic micro-organisms is therefore real.

On the contrary, an overdose can also have adverse effects on the consumer. Maximum sulphite levels exist for dried fruits and it is important to respect these in order to prevent consumer intoxication.

To ensure that the latter are made aware of the presence of sulphites, their presence must be clearly mentioned on the label where their concentration exceeds 10 mg/kg.

7.5.5. Risks when placing fruits on trays

As explained above, if the fruits are poorly placed on the trays and are overlapping, drying may be poorly executed. This overlap area where the drying has been poorly carried out will therefore have a higher water activity than the rest of the product, and micro-organisms may develop there. It is therefore important to carry out a visual inspection after placing the fruit on the trays to ensure that the fruits do not overlap.

7.5.6. Control of drying time

The preservation process used in the case of dried fruit is drying. It is therefore essential that this stage is carried out correctly.

This means keeping to the time of the fruit should remain in the dryer and reaching the temperatures indicated to ensure that the water content of the products at the end of production is indeed equal to that expected.

If the product is not sufficiently dried, it will lead to high water activity, which may in turn cause the development of micro-organisms, especially mould or even pathogenic microbes.

7.5.7. Control during storage of finished products

The **storage conditions of the finished products are essential** to meet sanitary standards. Indeed, if the dried fruits are stored in enclosed and humid places, the risk of moisture ingress is great. If the water content of the product rises, it is likely that the food is no longer stabilised and that the development of potentially pathogenic micro-organisms will occur.

Mould is the organisms most likely to develop first on dried fruit stored in excessively humid conditions. This should be avoided as far as possible, as some types of mould are responsible for the production of mycotoxins which can have a negative impact on consumer health.

Dried products must therefore be stored in dry and well ventilated places.

Hazard	Stage	Type of hazard	Acceptable level	Preventative measures
Pesticide residues	Harvest	Chemical	Pesticide residues below the MRL defined by substance and by type of fruit	Compliance with instructions for use (GAP and GPPP)
Presence of mycotoxins (e.g. OTA or ochratoxin A)	Harvest	Chemical	Maximum concentration defined by substance	Sorting fruit, removing rotten or damaged fruit, avoiding collecting fruits that have fallen to the ground
Presence of pests on non-dried fruit	Cutting	Biological	No pests on the production premises	Effective control plan Measures to prevent entry (mosquito net, etc.)
Excessive sulphite content	Sulphuring	Chemical	Defined by *Codex Alimentarius* standards or national regulations	Follow the manufacturer's recommendations
Sulphite content too low	Sulphuring	Biological	If the product has a water activity > 0.65, then the sulphites must be supplied in sufficient quantity to prevent the growth of micro-organisms	Follow the manufacturer's recommendations
Allergenic nature of sulphites	Sulphuring	Chemical	Sulphite content reduced to the minimum possible	Indicate the presence of sulphites where the concentration > 10mg/kg
Fruit poorly placed on trays	Placement on trays	Biological	No overlap of fruits	Visual control

Insufficient drying	Drying	Biological	Moisture content below the expected limit defined according to the fruit and the method used	Adherence to drying times and temperatures Include water content measurements in the control/ monitoring plan
Mycotoxins in the finished product (e.g. aflatoxins B1, B2; G1 & G2; OTA)	Storage	Chemical	Maximum concentration defined by substance (between 2.0 and 4.0 µg/kg for aflatoxins; 10 µg/kg for OTA)	Store the finished products in an enclosed and well ventilated area

Caution: Care should also be taken to avoid contamination by polycyclic aromatic hydrocarbons (PAHs), which are particularly toxic, if fumes are produced when heating the air in dryers or drying over a fire.

7.6. TECHNICAL APPENDICES

ATESTA gas dryer data sheet

This type of dryer is the most common. PAFASP (Burkina Faso) has published a data sheet that has been reproduced below.

Energy: natural convection gas dryer

Capacity: 5 kg of fresh mango slices per tray, *i.e.* 100 kg per dryer.

Gas consumption: 0.6 to 0.8 kg of gas to obtain 1 kg of dried mango

Drying time: 18 to 24 hours, depending on the drying period

Operation: after lighting the burners and loading the dryer, follow the recommended drying temperature depending on the variety. Rotate the trays every two hours so that each slice can benefit from the heat from the burners.

Optimal mango drying conditions: the dryers must be cleaned and preheated 30 minutes to an hour before the introduction of the trays containing the products to be dried. Mangoes should remain in the dryers for 18 to 24 hours. The trays are rotated every two hours so that each tray moves down to the hottest area to promote quick and even drying. The temperature is maintained at 75 - 80°C over the first three trays.

Dryer maintenance: clean the mesh screens before each drying cycle. They are used to catch insects. Regularly clean the burners to obtain a blue flame. Heat for up to 90°C for 30 to 45 minutes, twice a week, to prevent termite attack.

Caution: the gas used is butane, which is very flammable. It is very dangerous. Handling must be done with care. Protect the gas cylinders and provide at least two fire extinguishers.

Requirement estimations

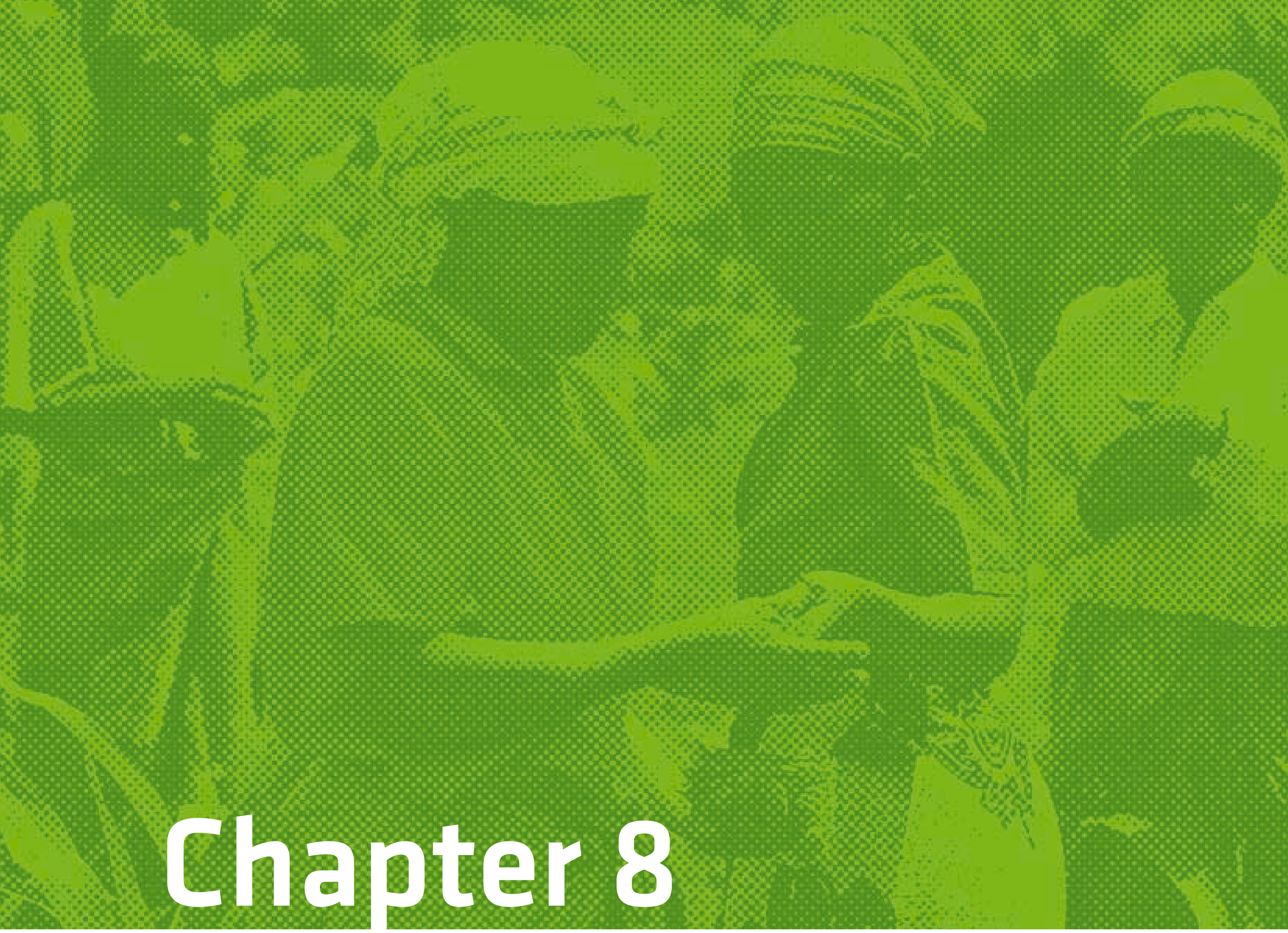
These estimations are important because they facilitate performance evaluation (losses, gains). The example below assumes an **order for one tonne of dried mango** packaged in 100g bags.

Estimated raw material requirement: you need an average of 15 kg of fresh mangoes to obtain 1 kg of dried mango. Simply calculate as follows: 1,000 kg x 15 kg = 15,000 kg of fresh mangoes.

Estimated gas requirement: you need an average of 0.80 kg of gas to obtain 1 kg of dried mango. Simply calculate as follows: 1000 kg x 0.80 kg = 800 kg of gas. One gas cylinder weighs 12 kg, so you will need: 800 kg/12 kg = 67 gas bottles.

Estimated packaging requirement: the customer requests bags of 100 g (primary packaging) arranged as 100 per box (secondary packaging of 10 kg):

- number of 100 g sachets: 1000 / 0.100 = 10.000 sachets
- number of 10 kg cartons: 1000/10 = 100 cartons



Chapter 8

Preparation of frozen products

8.1. REFRIGERATION AND FREEZING: DEFINITIONS

8.1.1. Cold storage

Both **freezing** and **refrigeration** involve lowering the temperature to in order to extend the shelf life of foods. The cold holds powers of preservation for food through two effects.

- **A thermal effect** of lowering the rates of biological reactions of development (metabolism of micro-organisms) and of biochemical and enzymatic reactions which can also adversely affect the preservation of food.

  There are three key temperatures to remember:

  - +3°C: eliminates risks due to pathogenic and toxigenic bacteria;
  - -10°C: prevents all bacterial multiplication;
  - -18°C: prevents all microbial multiplication (including yeast and mould).

- **A second effect, even more powerful, but which only occurs during freezing and deep freezing: the reduction of water activity.** In this case, the crystallised water becomes unavailable for all reactions (biological, chemical and enzymatic), which explains why freezing and deep freezing allow much longer storage times than refrigeration.

8.1.2. What is the difference between refrigeration and freezing?

During freezing, the temperatures that occur are much lower than during refrigeration, however the **essential difference between the two processes is the formation of ice crystals.**

- **A "chilled" product is simply cooled and stored in a fridge or cold room.** As long as it remains in the refrigerated state, the cells of plant tissues do not degrade. They remain alive, at least for a certain time (which depends on the plant species), even if the general metabolism (e.g. respiration) is considerably slowed due to the low temperatures. Metabolism is slowed, but not completely stopped. This is why products wilt when they lose their water, and some micro-organisms can continue to grow even at temperatures < 10°C. Bacteria of the genus campylobacter (e.g. *C. jejuni*) survive well at refrigeration temperatures (0°C to 10°C). Bacteria growth rates of 10 have been observed in grated carrots stored in the fridge for 24 hours. In general, the more the products are "worked", the more they become potentially contaminated and the less time they can be kept fresh in a regular fridge.

  In a **refrigerator**, the main compartment maintains an average temperature of < 5°C (in the middle), but in all cases > 0°C and ideally between +4°C and +7°C depending on location (middle, top or bottom, in the compartment for fruits and vegetables sensitive to too low temperatures). However, temperatures of +10°C are not uncommon in some domestic refrigerators, where thawing is not conducted in a timely manner or due to faulty seals.

- **Freezing is any technique aimed at making a product enter a solid state through forced cooling techniques.** At freezing, all metabolic activity ceases and is non-reversible. Freezing is most often used to describe the state of water and the products that contain it.

The technique consists of lowering the temperature of a product and keeping it, in a freezer, below the melting temperature of ice (0°C) in order to suppress any biological activity (which depends on the presence of water in the form of liquid), including chemical and enzymatic activity (for very low temperatures). It therefore combines the favourable effects of low temperatures and the transformation of water into ice. It is also the least destructive technique, provided it is carried out correctly: freezing must be rapid, and the storage temperature must be sufficiently low. The aim of successful thawing is to obtain a product of a quality as close as possible to that of the original product.

Freezers are present in many households in the form of a chest or cabinet, integrated into a fridge or standalone. **Domestic freezers** generally drop to -18°C, or even -26°C (four-star domestic freezers), which is sufficient for artisanal production. In this type of freezer, fruits and vegetables can be stored for about a year (compared to 2-3 months for minced meat).

On the other hand, the **deep-freezing technique used by food manufacturers** is based on exposure to temperatures ranging from -35°C to -196°C, which further extends the expected storage life.

Whether frozen or deep-frozen, products must be kept at a storage temperature of -18°C.

8.1.3. Advantages and disadvantages of freezing

Today in Europe it is estimated that at least 50% of our food has undergone refrigeration treatment. Cold is therefore an essential component of the agro-food industry: in the storage of raw materials (raw milk kept in a refrigerated tank at 3 or 4°C), during the manufacture of products (blocking the acidification process using cold temperatures of 3°C for the manufacture of yoghurts), for preservation (storage of fresh food in cold rooms), transport (refrigerated vehicles) and distribution (refrigeration or freezer cabinets). However, besides certain undeniable benefits, the freezing and deep-freezing processes have many drawbacks in the case of fruits and vegetables.

8.1.3.1. Advantages

- No micro-organism is capable of growing at below -10°C. Storage at -18°C prevents any microbial activity (but does not kill them).
- The transformation of water into ice freezes the tissues and isolates the water which is no longer available as a solvent or reagent.
- The nutritional value of the food is preserved.

8.1.3.2. Disadvantages

- The formation of ice crystals can lead to **mechanical degradation** in the texture of the plant tissue (especially where there is a lot of water and little cellulose). This technique must therefore be well mastered if the thawed product is to retain its sensory properties (mainly colour, flavour and texture).

- **Increase in volume**, which will depend on the amount of water present. When water turns to ice, its volume increases by about 9%. Thereafter, as it cools, the ice undergoes a slight contraction. Other constituents, specifically lipids, contract during freezing. These variations in volume cause internal tensions which can reach several hundred bars. **In the case of fruits and vegetables, the tearing of cells and tissues occurs, as well as exudation on thawing** (e.g. at -18°C: +9% for water; +8.3% for apple juice; +4% for whole raspberries). Fruit can sometimes burst when the expansion of the interior occurs following the formation of an outer frozen shell.

  The increase in volume is usually proportional to the moisture content of the food. The small increase in volume of whole fruits is explained by the presence of gas in the vacuoles: these gases are compressed and partly expelled during freezing.

- **Degradation of coloured pigments** during proteolysis[47]: blanching is therefore recommended (rapid boiling to destroy enzymes) for sensitive vegetables (mainly green vegetables).
- **Appearance of unpleasant flavours** due to oxidation, such as the pungent "hay" taste of green vegetables. It is recommended to add an antioxidant such as ascorbic acid (vitamin C) to limit the phenomenon. This reaction occurs under the control of oxidative enzymes or the spontaneous reaction with dissolved oxygen.
- **Appearance of brown spots** on some plants: this is an enzymatic, oxidative browning reaction (or "enzymatic browning") which corresponds to the plant's defence against the aggression represented by thermal shock. This can be remedied by blanching certain vegetables before freezing them.
- **Desiccation of the surface**: the cold dries out products, increasing the importance of well-packaged products during cold-storage. Desiccation can also include sublimation; the strong reaction of the ice formed on a surface, where solid water turns into vapour without passing through a liquid state.
- **Formation of frost on packaging**: this is a periodic phenomenon of freeze-drying which results from temperature fluctuations. When the outside temperature decreases and becomes lower than the temperature at the surface of the product, there is migration of water vapour by sublimation to the lining of the packaging (or the cold room) and a subsequent deposit on the colder surface in the form of frost. This phenomenon can also occur the other way around. It is important for packaged products and is a sign of an intermittent operation over long cycles or a significant break in the cold chain.
- **Energy-intensive processes** during freezing, but also for the long-term preservation of food.

47 Proteolysis: proteolysis is the breakdown of proteins into their basic fragments (amino acids) via hydrolysis catalysed by proteolytic enzymes (proteases or hydrolases).

8.2. PHYSICAL PRINCIPLES OF THE FREEZING PROCESS

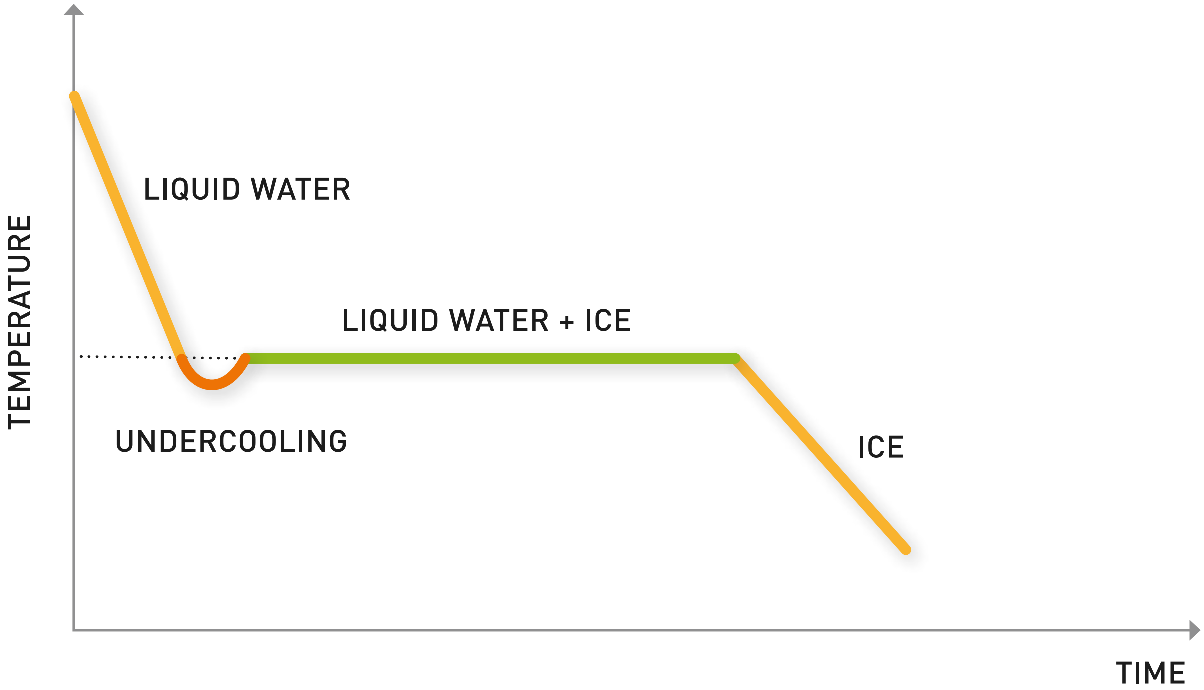
8.2.1. Stages of ice crystal formation

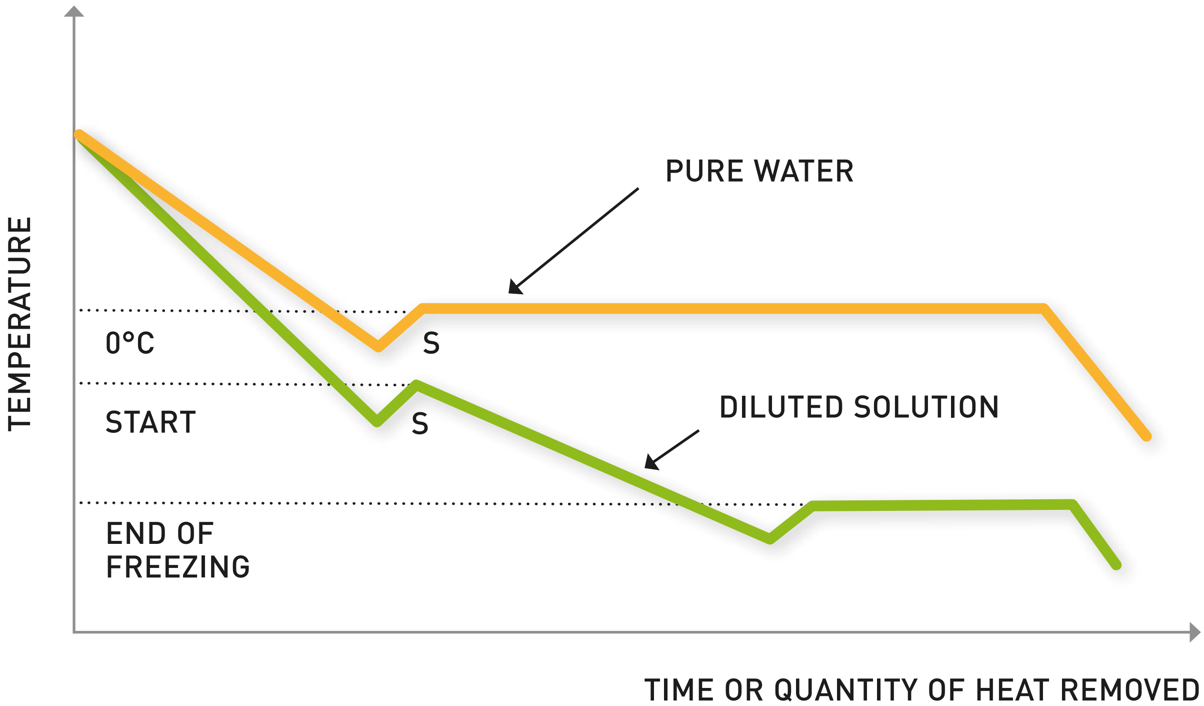
8.2.1.1. A quick recap of the theory of changes of state

When liquid water is cooled, the thermal motion of the water molecules decreases and the hydrogen bonds gradually stiffen. The water molecules then form a rigid, highly organised structure: the water has turned into ice. At normal atmospheric pressure (1 atmosphere or 1013.25 hPa), when the temperature of liquid water is lowered below 0°C (or 273.15 K), that water turns to ice.

The melting temperature of ice at ordinary pressure is 0°C. However when pure water is cooled gradually, **freezing does not occur as soon as the temperature reaches 0°C**. The formation of ice crystals (nucleation) is always preceded by "supercooling". This state occurs when we cool water quickly and then exceed the freezing point (due to a mechanism of obstruction to the formation of a crystal lattice), then, by intake of energy (impact or impurity), a release of heat will occur, which raises the temperature to around 0°C and solidification takes place. Supercooling is therefore "the state of a material which remains in the liquid phase while its temperature is lower than its solidification point"; therefore, **water remains liquid for a certain time at a temperature below 0°C**. A small disturbance (e.g. presence of dust, crystals)may then be sufficient to abruptly trigger the change of state from liquid to solid.

This phenomenon is of particular importance in the case of small volumes (drops < 1 mm), which explains the difficulty of nucleation of the water in cells and in particular, in micro-organisms.

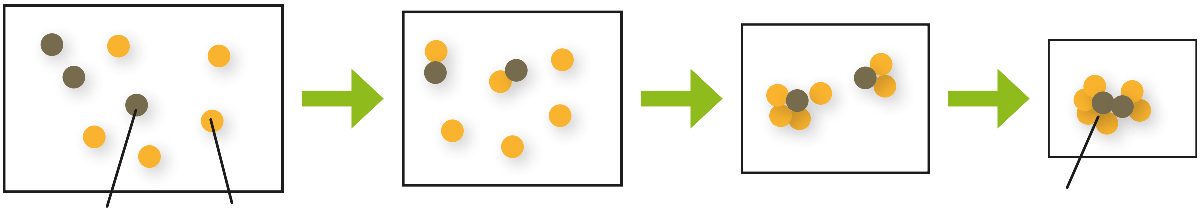




Representation of the transformation of water into ice and the phenomenon of supercooling: freezing curves of water and an aqueous solution

During supercooling, the crystalline aggregates of water molecules are in a dynamic state: very rapid formation followed by destruction. It is only above a critical size that **a crystal is stable and could serve as a seed for crystal growth (nucleation).** This critical size seems to be temperature-dependent and is smaller the lower the temperature. It is very unlikely for nucleation to occur at melting point, however this probability reaches a maximum value at - 41°C.

Nucleation[48] is **stimulated by the presence of crystals of various insoluble salts** or of solid particles of various natures (dust). In foods, nucleation is heterogeneous and supercooling is low.



8.2.1.2. Crystal growth

The shape of ice crystals (spherulites, rosettes, dendrites, platelets or hexagonal stars) **depends on the growth rate, and therefore on the freezing temperature.** The growth of crystals results from water molecules migrating within the medium and combining with an existing seed. It can take place at a temperature close to freezing point. In practice, in food, **the rate of crystal growth depends on the rate of heat removal** and is at a maximum when the temperature of the medium is below -80°C.

- **Rapid freezing or deep-freezing**, during which foodstuffs are stabilised by rapidly lowering their core temperature to -18°C. This technique allows the formation of many small ice crystals which do not spoil the food. As a result, only a small amount of exudate is generated during thawing.
- **Slow freezing** is applied to products which, by their appearance or method of harvest, cannot meet certain requirements, for example, the speed of freezing to which frozen products are subjected. The food is cooled slowly, resulting in the formation of ice crystals that are relatively large in size compared to the cells in the product.

In the case of solid or high viscosity products, the crystal size may vary. At the periphery, crystals form quickly and are small in size; inside, they grow more slowly and reach a larger size, as heat transfer is more difficult. Cell barriers also slow crystal growth.

At very low temperatures, the mass transfer is the limiting factor, because viscosity slows the movement of water molecules. This also occurs in concentrations where substances in solution (salts, alcohols, sugars, proteins, etc.) slow down the growth of ice crystals.

48 Nucleation is a phenomenon of initiation (or acceleration) of a spontaneous process of self-assembly from a nucleus or a "seed". In the case of freezing a droplet: phenomenon according to which the first crystalline seed appears; the aggregation of the first crystalline seeds that form ice.

Growth rates of ice crystals (according to Cheftel)

Liquid	Temperature	Crystal growth rate (in mm/second)
Water	-9.1°C	61
NaCl 0.1 M	-9.1°C	41
Ethanol 0.1 M	-9.1°C	29
Saccharose 0.1 M	-9.1°C	6.6

8.2.1.3. Crystal size

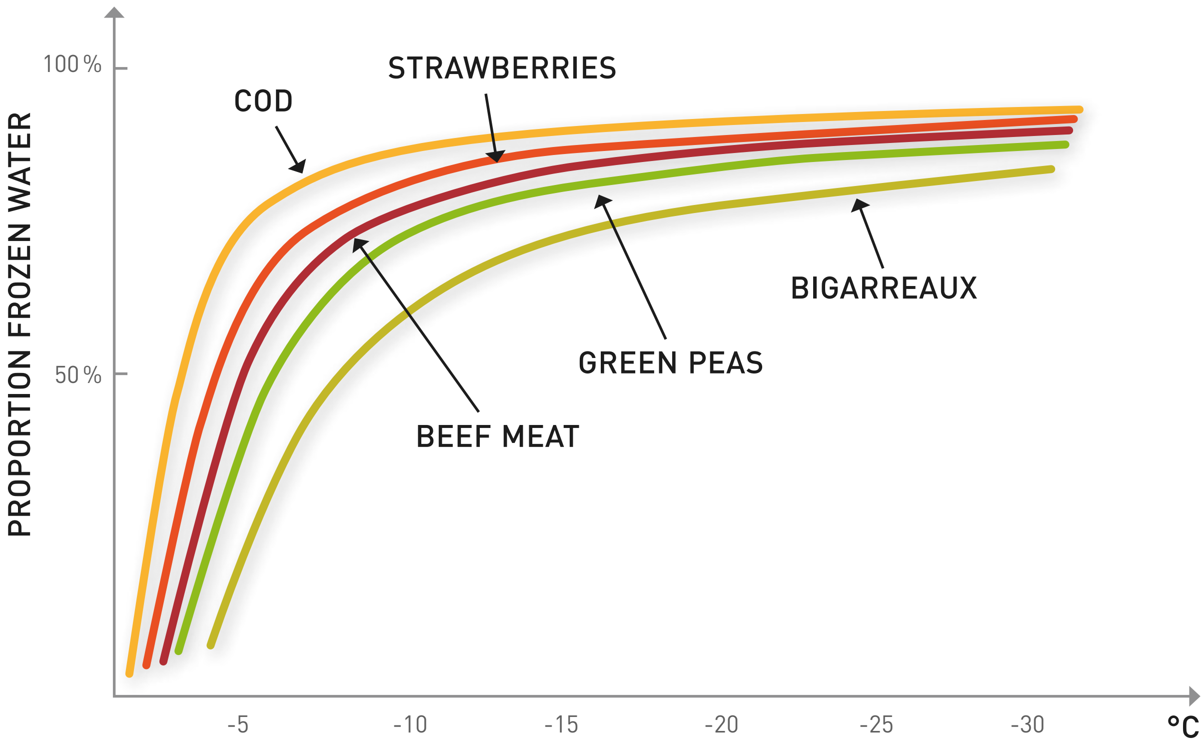
The size depends on the **number of seed crystals** originally formed in the liquid medium. Regulating nucleation by temperature allows the creation of crystals of a desired size. At **low temperatures**, nucleation is rapid and the large number of seeds give rise to an abundance of **small crystals**. At **temperatures close to melting point**, nucleation is slow, the nuclei are few in number and the **crystals are large**.

8.2.1.4. Recrystallisation

During storage in a frozen state, the crystal system evolves due to recrystallisation phenomena: **some ice crystals get bigger at the expense of smaller crystals that disappear.** This phenomenon is all the more rapid as the temperature gets closer to the melting point. Even at -60°C, the frozen aqueous system can undergo noticeable changes.

8.2.2. Influence of the proportion of frozen water in food

The diagram below represents the proportion of water in a frozen state in various foods, whose soluble dry matter content varies from approx. 10% (cod) to approx. 20% (Bigarreaux cherries), in relation to temperature. At the usual temperature for frozen food storage (-18°C), a significant part of the freezable water remains liquid (2 to 5%) and has solvent and reagent properties. Some of the degradation reactions that continue are due to **the existence of residual liquid spaces** containing high concentrations of solute. In many cases, it would be more advantageous to store at temperatures below -18°C, however the cost would become prohibitive in this case.



Proportion of frozen water in different foods depending on storage temperature

One of the consequences of freezing is the **increase in the concentration of solutes** present in the liquid spaces in foods, with several consequences.

- When dealing with solutes capable of reacting with each other, we observe an increase in the reaction rate during freezing down to approx. -15°C, despite the decrease in temperature. This acceleration starts at -5°C; however from -15 C the reaction rate slows. The highest rates have been observed during reactions involving oxidation, hydrolysis and protein insolubilisation. The enzymatic reactions are generally not accelerated.
- The increase in the concentration of solutes also leads to the modification of other properties of the medium: pH, osmotic pressure[49], redox potential[50], surface tension[51], etc. The action of these factors associated with the disappearance of water causes unfavourable changes in the food. For example, a drop in pH, an increase in ionic strength or the mere departure of water can lead to protein aggregation (milk caseins, lipoproteins in egg yolk).

All of these effects are limited when freezing is rapid and the storage temperature is very low.

---

49 Osmotic pressure: pressure which prevents a solvent from passing through a semi-permeable membrane, a force determined by a difference in concentration between two solutions located on either side of this membrane.

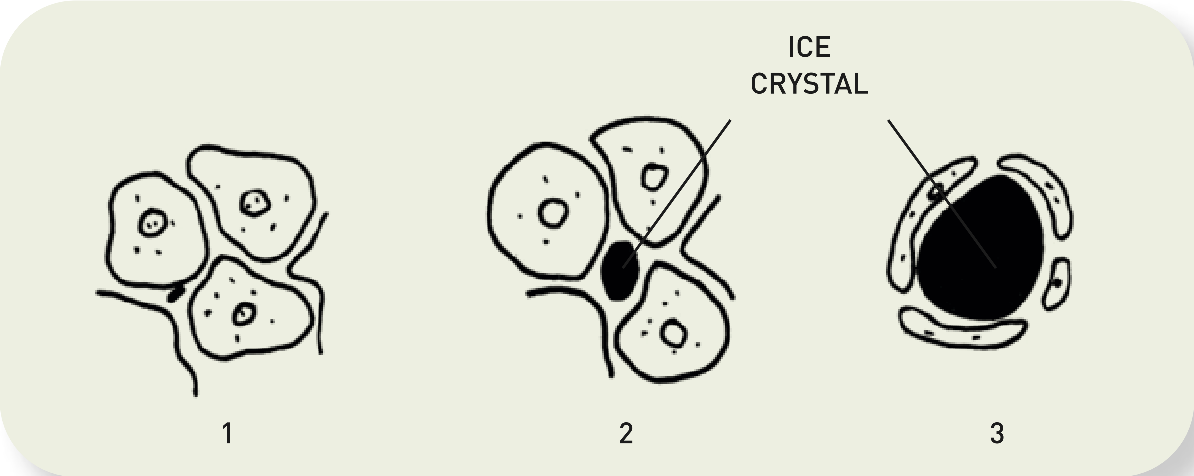
50 Reduction potential (also abbreviated to "redox potential"): the thermodynamic quantity that measures the oxidising or reducing power of a redox system. The more oxidising power a system has, the more reductive it is in capturing electrons, and the higher its redox potential. The more reductive it is, and the more readily it gives up electrons, the lower its redox potential.

51 Surface tension: physicochemical phenomenon linked to molecular interactions which consist of improving the adhesion of a body to the surface of a liquid.

8.2.3. Crystallisation and freezing rate

The freezing of a tissue begins with the crystallisation of water from extracellular spaces (because the concentration of solutes is less than in cells).

- When freezing is slow (< 1°C/minute), extracellular crystallisation (which increases the local concentration of solutes) causes the progressive dehydration of cells by osmosis. **Large ice crystals form and expand** the extracellular spaces, while plasmolysed cells[52] shrink considerably in size. This dehydration further lowers the likelihood of intracellular nucleation. In slowly frozen cell suspensions, intracellular crystals are not observed except in non-frost resistant plant cells, in vegetables frozen after blanching, or in tissues frozen a second time. This **movement of water**, which can become irreversible if it exceeds a certain level, largely explains the decrease in turgor, the exudation that is observed when thawing many foods. **It is the main cause of the softening of plant tissue.**



Observation under a microscope shows that large extracellular crystals separate fibres cells whose walls are often torn. Gradual development of ice crystals in tissues during slow freezing.

The expulsion of one part of the cells has the effect of bringing enzymes into contact with their substrate, in particular the polyphenol oxidases and polyphenols normally located in separate cell compartments.

- **When freezing occurs rapidly**, crystallisation occurs almost simultaneously in extracellular spaces and within cells (by nucleation around cell organelles and possibly by penetration of extracellular crystals through cell walls). The volume of **water displacement is small**, producing a large number of small crystals; the changes in texture linked to the water leaving the cells by osmosis are markedly less significant. Under the microscope, it is observed that damage to the plant membranes is reduced. It should be noted that in all cases, the formation of intracellular crystals, regardless of their size, destroys the internal organisation of cells (cytoplasm, organelles), stops or profoundly modifies the metabolism, and causes the death of cells and tissue.

52 Plasmolysis: the cellular state of the plant cell where, following water loss, the membrane detaches from the pecto-cellulosic wall. The resulting decrease in pressure causes the soft tissue to collapse.

Slow or rapid freezing?

For fruits in general, rapid freezing retains the texture better.

For blanched vegetables, this is not the case.

8.2.4. Thawing products

Thawing food is a **slower process than freezing** because an aqueous layer forms first on the surface, then in the outer layers of the product. However, the thermal conductivity of water is about four times lower than that of ice, which conducts heat all the better the colder it is.

During thawing, the mass is quickly brought to a temperature slightly below melting point. Then the quantity of heat required to melt the mass is slowly transferred through the outer aqueous layer. The product remains at a temperature close to 0°C for a long time, creating a risk of the development of micro-organisms, including pathogens.

It is therefore preferable to thaw at a quick rate.

Vegetables can be immersed directly in boiling water.

Fruits are usually thawed at room temperature.

In industry, there are various processes.

- **Blast thawing**: at the start of the operation, high humidity (around 90%) is added to the air in order to improve the convection coefficient and to prevent the product from drying out. When the surface area is thawed, air is blasted at +4°C with a humidity of around 70%.
- **Vacuum thawing**: this process involves condensing water vapour at 18 - 20°C on the surface of the product to be thawed in a vacuum chamber.
- **Thawing in water: this technique is very widespread despite it not being hygienic.** In order to limit microbial growth, the water must be at a temperature below 20°C. The water is circulated in order to increase the convection coefficient.
- **Microwave thawing**: this technique is significantly faster than conventional methods. Unfortunately, since microwaves are absorbed much more quickly by water than by ice, the peripheral freezing front which develops shields the penetration of microwaves into the still frozen centre, so that the surface of the product can be cooked even before its central part is thawed. This effect may be limited by intermittent microwave exposure alternated with resting time.

8.3. FREEZING AND RISKS OF SPOILING

Even whilst frozen, a food product can degrade for various reasons: enzymatic reactions, oxidations, crystal growth, proliferation of micro-organisms during repeated phases of freezing/thawing (e.g. repeated power outages, frequent in some southern countries).

8.3.1. Degradation reactions

- Enzymatic reactions: enzymatic browning of frozen fruits in a raw state. Solutions:
  - addition of ascorbic acid, sugar or sulphur dioxide;
  - blanching: most vegetables should be blanched before freezing, as some enzymes retain active even at very low temperatures.
- Non-enzymatic reactions: oxidation of lipids (e.g. peas), vitamin C (strawberries), carotenoids, aromas. The degradation of anthocyanin pigments (strawberries) or chlorophyll (spinach, green beans, Brussels sprouts) is also a factor limiting storage time.
- Flocculation of suspended matter: in fruit juices, pectin can undergo destabilisation.
- Recrystallisation of ice crystals with an increase in their size, which leads to a change in the texture of various foods.
- Partial desiccation due to fluctuations: packaging can provide good protection if it is impermeable to water vapour and if it adheres to the product (vacuum or shrink packaging). If the packaging does not stick to the product, there may be surface desiccation on the food and water condensation on the inside of the packaging (frost). The packaging must also be impermeable to oxygen and light.

8.3.2. Effects on micro-organisms

From the above, we understood that freezing acts in several ways on microbial flora:

- lowering the temperature reduces the multiplication rate of bacteria;
- the transformation of water into ice decreasing the quantity of water available for micro-organisms, freezing completely inhibits their multiplication;
- the change of state from water to ice causing alterations in the structure and metabolism of bacteria capable of causing the death of certain micro-organisms.

In fact, the crystallisation of water **modifies microbial structures** both through its mechanical and physicochemical effects. Lesions of membranes (perforation, denaturation of proteins) have an effect on cell permeability and are accompanied by the release of vital compounds such as nucleotides, nucleic acids, peptides, mineral ions, etc., resulting in a loss of cell viability.

The following points should be noted:

- **Freezing has no bactericidal effect.** Freezing has an effect on the metabolism of bacteria. It reduces the initial microbial population, but only to a small extent. For the most sensitive (Gram-negative) micro-organisms[53], freezing reduces the population by 90%. Most Gram-negative bacteria lose their ability to use mineral nitrogen in their protein synthesis and make use of existing peptides for their growth. Some strains of pseudomonas lose their ability to produce their pigment.
- **Slightly negative freezing temperatures are more lethal than strongly negative temperatures**: between -4°C and -10°C, a greater number of micro-organisms are inactivated than at between -15°C and -30°C, a temperature range at which inactivation is practically zero.
- **Slow freezing has a more detrimental effect** than rapid freezing on the survival of bacteria because cells are exposed to cryoconcentration for a longer period and the ice crystals are larger.
- The longer the storage period, the greater the destruction of micro-organisms.

8.3.3. Why should a thawed product not be refrozen?

We often hear recommendations that you should not refreeze a product that has been thawed. The multiplication of micro-organisms and bacteria is often thought to be responsible. The process of refreezing is however carried out by manufacturers. At home, this practice should be avoided, for various reasons.

8.3.3.1. Freezing and bacteria

When food is frozen, ice crystals form in cells which can be more or less destroyed depending on its nature. The same is true for some of the bacteria it contains. On the contrary, other bacteria remain dormant and resume their proliferation once the product is thawed. In effect, the destroyed cells are more easily accessed and constitute more food for those bacteria that have withstood the cold.

8.3.3.2. Freezing and toxins

When a frozen product is thawed and then refrozen again, **the number of pathogenic micro-organisms increases**. However, these **micro-organisms generate toxins** which, once released, have harmful effects on health. In concrete terms, the more micro-organisms there are, the higher and more frequent the risk of causing food poisoning.

53 Gram-negative bacteria: Gram-negative bacteria are detected by a staining technique called Gram stain. Gram-negative bacteria appear pink under the microscope. The staining technique is based on the cell membrane and wall properties of the bacteria (bimembrane structure).

8.3.3.3. The thawing and refreezing process

When food is thawed **by being left in the open air**, the process takes place at room temperature, and therefore takes longer. This period is **favourable to the multiplication of bacteria.** The same is true if you opt to cook it quickly over a low heat.

When carried out at home using a home freezer, refreezing is also time consuming. It takes time for the refreezing process to become effective. During this time, bacteria have a lot more time to grow exponentially.

In concrete terms, the phases of freezing, thawing and refreezing end up making food very dangerous for health. Indeed, between the first freezing and the first refreezing, almost a thousand more bacteria exist.

These micro-organisms, especially those which are pathogenic, can however be eliminated. Cooking is a good way to do this if it lasts for a **certain period at a temperature of at least 125°C**. Therefore, thawing and then cooking a product at 100°C, for example, will not be sufficient to eliminate micro-organisms. The same goes for the bain-marie.

8.3.3.4. Reduction in taste

As the cells are destroyed, **the texture of the product is also denatured** and the taste of the food is thereby transformed. To get a better idea of what is happening, it is possible to conduct an experiment. When fresh raspberries are frozen, they retain their shape, their cells are simply "crystallised". On the other hand, when they are left in the open for a while, they become increasingly crushed. They don't taste the same as they did before. This is exactly the same phenomenon that occurs for other products.

8.3.4. What is the shelf life of a frozen product?

The shelf life depends largely on temperature. For example, a temperature of -30°C can be used to store fish for 6 to 8 months. We do the same for ice cream, to avoid the formation of ice crystals that are too large. These very low temperatures are very expensive and difficult to maintain during transport and especially in points of sale.

In practice, a temperature of -18°C is used for most foods.

Where a product is marked "frozen", this guarantees that it has been frozen as quickly as possible at a temperature of -18°C or below, and then maintained at that temperature throughout storage.

8.4. PREPARATION PROCESSES FOR FROZEN PRODUCTS

8.4.1. Small-scale fruit and vegetable freezing

What could be easier than freezing your food to preserve it efficiently? All you need is a freezer that can reach a temperature of below -18°C. Fruits, vegetables or even leaves and aromatic herbs can all be easily frozen. Freezing is a very simple way to store food well, however **there are a few rules that must be followed**.

1. Use fresh or dry foods that can tolerate the freezing process well.
   - Ideally, **produce should be frozen when it is very fresh, if possible immediately after harvest,** in order to preserve the vitamins. The smaller the delay in freezing, the better. It is better to avoid leaving them lying around for several days, even in the fridge, before freezing. Healthy harvested fruits or vegetables can be frozen.
   - On the other hand, avoid freezing raw potatoes and vegetables to be eaten raw. The texture of salads, cucumbers, tomatoes and the like, change during freezing. However, this is not a problem where they are intended for cooking.
   - You can also freeze fresh leaves (e.g. rolled up, as in Sierra Leone) or well dried leaves and herbs.
2. Preparation before freezing.
   - Vegetables: before placing them in the freezer, **vegetables are washed and cleaned thoroughly**. **Most of them should be blanched** to inactivate the enzymes and destroy many of the micro-organisms. Eliminating these sources of degradation then guarantees better preservation of colours, flavours and textures. Blanching also helps retain a certain amount of vitamins, especially if the vegetables are to be frozen for a long time. Caution: **freeze cold foods only,** otherwise frost will appear.
   - Fruits: before freezing, check the condition of the fruits. If they show signs of disease or pest attacks, it is best to avoid freezing them. Then, dry the healthy fruits without washing them. Small fruits should be frozen whole, larger fruits in pieces and stone fruit once pitted. Fruits take up less space if they are frozen in the form of compotes, coulis, marmalades or syrups.

     Fruits intended to be eaten raw must be sweetened to retain their flavour, colour and vitamin C content. To coat the fruits, mix in a dish:
     - 200 g of sugar per kilo for acidic fruit;
     - 100 g of sugar per kilo for sweet fruit.

     We can add lemon (supply of vitamin C) to fruits which blacken, and sweeten red fruits (strawberries, raspberries, currants, etc.). They then keep better and less sugar is used in the final preparation.

3. Cutting and preparation of small portions.

   Products should preferably be cut into small portions before freezing. The cold penetrates them faster: this prevents the temperature of the freezer from heating up, which could happen if too much tempered food is put in at once. Most importantly, do not put hot products in the freezer. They can be cooled in the fridge before freezing.

4. Choose the right containers.

   - Containers are important for freezing. Preferably, these should be washable and reusable to reduce waste. The following can be used as packaging during freezing:
     - non-reusable plastic bags, which should be flattened to expel the air. The packaging should contain as little air as possible; a good solution is to use vacuum pouches;
     - thick aluminium foil (to prevent tearing) or plastic film;
     - reusable aluminium trays, provided they have been spotlessly cleaned;
     - plastic boxes (do not fill them to the brim, but leave at least 1 cm of space under the lid: as they freeze, the food will increase in volume).

     Plastic bags, boxes or glass jars must be hermetically sealed. This prevents the cold air from dehydrating and oxidising food. Keep any original packaging on (if there is any), which has the added advantage of retaining recommendations on use and an expiration date, which are always useful information.
   - To freeze your products, you must pack them in a perfectly airtight way. Packaging should be airtight and free of air, which will prevent moisture loss.
   - Liquids swell during freezing. To prevent glass containers from bursting under pressure, choose them larger than their food content: leave a space of 3 cm beneath the lids of jars.
   - To prevent fruits and vegetables from sticking together during freezing, spread them out on a baking sheet lined with baking paper, leaving space between each piece. Place in the freezer. Once ready, all that remains is to transfer them to their final container.

5. Labelling.

   When placing food in the freezer, always remember to label the containers. As a minimum standard, the following should be indicated:

   - the content, as some foods are difficult to recognise when frozen;
   - the number of servings included in the container;
   - the date of freezing: this makes it possible to recognise frozen foods and consume them in chronological order; they can be kept from a few months up to a year (for vegetables);
   - ideally, the best before date (depending on the type of freezer).

6. Thaw well and avoid refreezing.

   Thawing follows very simple rules. Thaw food slowly in a refrigerator, microwave or in cold water. Do not thaw at room temperature in order to prevent bacteria from growing. When you thaw a product, always use it within 24 hours. Food that is thawed and then refrozen contains a greater number of bacteria, which increases the risk of food poisoning. Freezing food also affects its taste and texture.

7. Work cleanly and methodically.

   Even in artisanal production, the basic rules of hygiene must be scrupulously respected, because otherwise you will also freeze your germs! The following precautions should be taken:

   - hand cleaning, personal hygiene;
   - cleaning of worktops;
   - cleaning pots, utensils, knives, spatulas, etc.;
   - regular cleaning of the freezer: the freezer must be kept clean, as well as the products stored.

   In a chest freezer (or cabinet), it is not always easy to store your products by following the FIFO rule (first in, first out), because the products are placed on top of each other, with the oldest likely to be found at the bottom. Some products may even get "forgotten" at the bottom of the freezer, stuck in the ice. Cabinet freezers make it easier to manage and store products: they are more expensive, but generally less bulky.

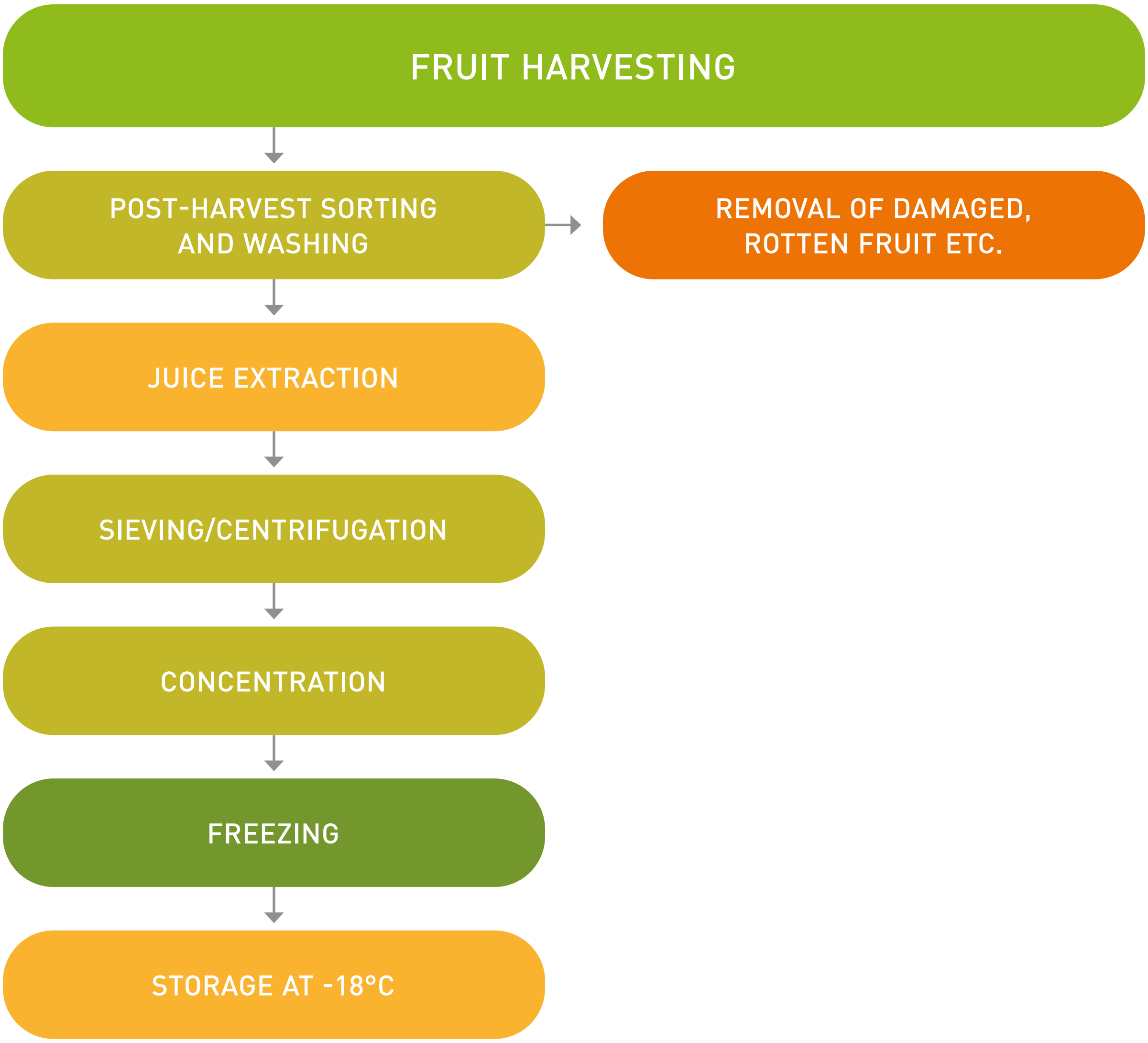
Chest or cabinet freezer

Upright freezer

8.4.2. Industrial preparation processes for frozen products

A wide variety of plant and plant-based products can be frozen (e.g. vegetables, fruits, etc.), and, for example, sold in 190 kg metal drums for the sale of fruit juice, fruit purée, etc. (e.g. unsweetened fruit purées or fruit juices such as lychee or pineapple prepared by SCRIMAD in Madagascar).

The basic process hardly changes.
For example, to produce concentrated fruit juices for freezing



For fruit purées, the juice extraction operations can be substituted with obtaining the purée.

We will therefore focus on the operation which is at the centre of the process: freezing.

8.4.3. Factors affecting freezing/deep-freezing times

It is important to know the freezing time for a specific product, because it will allow:

- the determination of the residence time or the flow rate of the product to be frozen (freezing tunnel);
- the correct size of equipment to be purchased.

The freezing time will depend on the **properties of the product**, but also on that **of the equipment used**.

a. Properties of the product to be frozen

- Quantity: mass of the product to be frozen.
- Initial and final temperatures.
- Humidity: the energy required increases with humidity.
- Specific heat (Cp in kcal/kg/°C): amount of heat energy to be removed to reduce the temperature of 1 kg of product by 1°C. For example, the Cp of water (1 kcal/kg/°C) is higher than all other food ingredients (e.g. lipid = 0.5 kcal/kg/°C). **Result: the more water a food contains, the more energy it will take to freeze it.**
- Thermal conductivity (in kcal/m °C)[54]: ice (1.9 kcal/m °C) > frozen food > water (0.51) > unfrozen food > lipids (0.05) > air (0.02).
- Density (air = thermal insulator).
- Geometry: shape and thickness.

b. Equipment properties

- Refrigerant temperature and temperature difference between product and refrigerant or air.
- Properties of the refrigerant: water, air, cryogenic gases do not have the same heat exchange coefficients.
- Cooling capacity (in kW or kcal/h or frigorie).
- Heat transfer coefficient (depending on the type of contact between the product and the refrigerant medium).

54 Thermal conductivity is a physical quantity characterising the behaviour of materials during heat transfer by conduction. It represents the energy (amount of heat) transferred per unit area and time under a temperature gradient of 1 degree Celsius per metre.

8.4.4. Freezing processes for plant products

The freezing processes common in the food industry use refrigeration sources that are either mechanical or cryogenic, or a combination of the two. Mechanical freezers are widely used on an industrial scale. There are several methods including:

- blast freezing: among the techniques used, we can distinguish freezing tunnels, plate freezers and direct freezing systems (cryogenic freezing);
- freezing by direct contact on a pre-cooled surface;
- cryogenic freezing by spraying a liquid (nitrogen or liquid CO_2) which evaporates on contact with the product.

8.4.4.1. Freezing processes using air

These freezing process can take place either in batches (static chamber or tunnel) or continuously (carrier strip or dynamic tunnel).

- **Static freezing chambers (using static air):**

The product is placed in stagnant air maintained at -20 or -30°C. A thickness of 0.2 cm of the product is frozen per hour (freezing time: from a few hours to several days). These are unfavourable conditions to produce a quality output, therefore this process is seldom used.

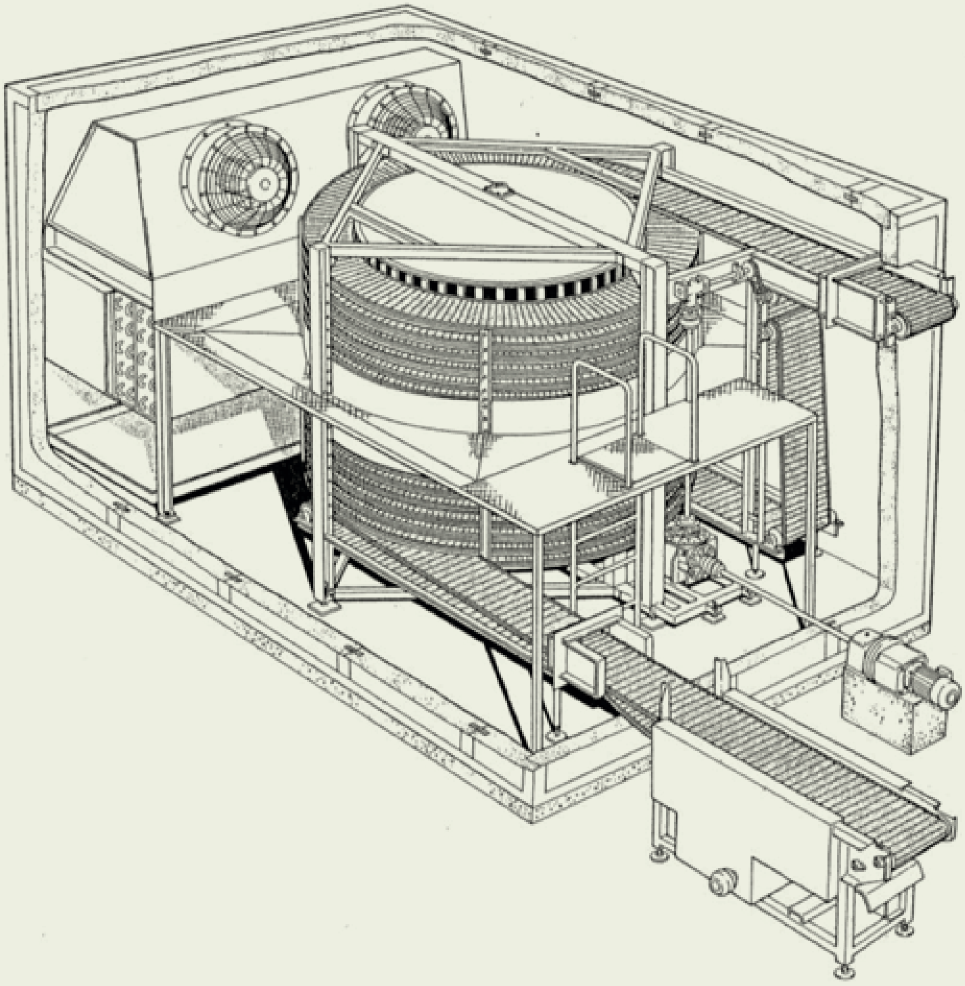
The devices **operate using batch processes**. These are simple heat-insulated and thermostatically controlled rooms. In order to avoid heat emissions inside, the fan motors are located on the exterior. Products are stored **on dollies or pallets**. This type of equipment is suitable for companies which have a wide range of products to process (meat, poultry, ready meals, ice cream in small jars, etc.).

- **Freezing tunnels (with moving air)**

In the freezing tunnels, air is cooled to -20 to -45°C while passing through the refrigeration unit evaporator. It is blasted on to the product by a fan, at a speed of 50 km/h. Then, it is recycled to be cooled again. The product is frozen at a rate of 3 cm in thickness per hour. The benefit of freezing tunnels is their flexibility of use. They are recommended where there is a need for several types of products, of different shapes and sizes, to be frozen. The drawbacks relate to the air, used as a refrigerating agent, which is very expensive and which tends to dry out the product on the surface, resulting in a loss of quality and yield.

Continuous flow processing freezing devices:

- **carton freezer tunnels**: products are placed in open packaging boxes which move continuously;
- **conveyor belt tunnels**: a conveyor belt ensures the flow of the product; the most conventional are linear devices which have the drawback of being bulky;
- **spiral devices**: use a belt which performs an ascending helical path inside the heat-insulated chamber; the belt is self-stacking; this system is particularly effective: the air circulation is directed from top to bottom against the flow of the products; the system is very compact, it can be equipped with an automatic cleaning and disinfection system.

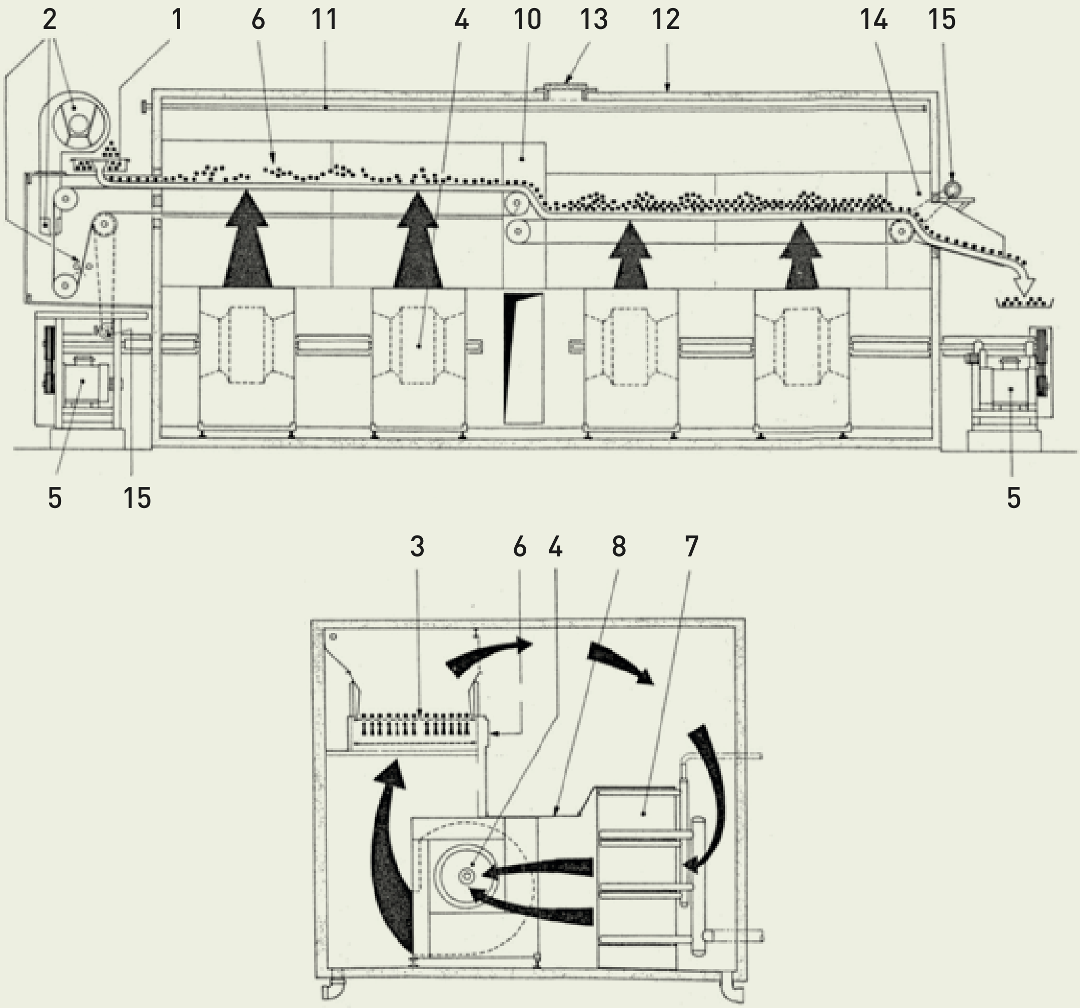


Mafart spiral freezer (source: Samifi Babcock)

- **Fluidised bed freezers (with moving air)**

This type of freezer is equipped with a mesh conveyor belt. Where the product to be frozen consists of small enough particles, it can be laid out in a layer of around 15 cm thick. Cold air then passes through this layer from the bottom to the top at such a speed that the product is carried upwards and agitated, *i.e.* fluidised. Peas, cut green beans, chips, strawberries, prawns, etc. can therefore be frozen in 6 to 15 minutes in an air temperature of -35°C without the risk of the individual pieces sticking together.

Due to the high freezing speed, dehydration is low. For the whole of the products surface area, each particle comes into contact with the air, which is why this system is known as Individual Quick Freezing (IQF).



1. Dispenser made of stainless steel, with product-dependent adjustable vibration frequency
2. Automatic carpet washer-dryer
3. Stainless steel mats with special mesh
4. Variable-flow centrifugal fans
5. Fan drive motors
6. Carpet control and inspection gate
7. Evaporator batteries made of steel tubes with flat fins, with decreasing pitch, hot-dip galvanised
8. Inspection gateway
9. Product in the process of being frozen
10. Transfer station between the two zones
11. Steam defrosting ramp
12. Insulated cabin
13. Control gate for the deep-freezing process. Location at the customer's choice
14. Unloading station with stainless steel channel
15. Gearmotor for carpet progress with speed variation adjustable according to the product

Fluidised-bed freezer (source: Samifi Babcock)

8.4.4.2. Freezing processes using contact

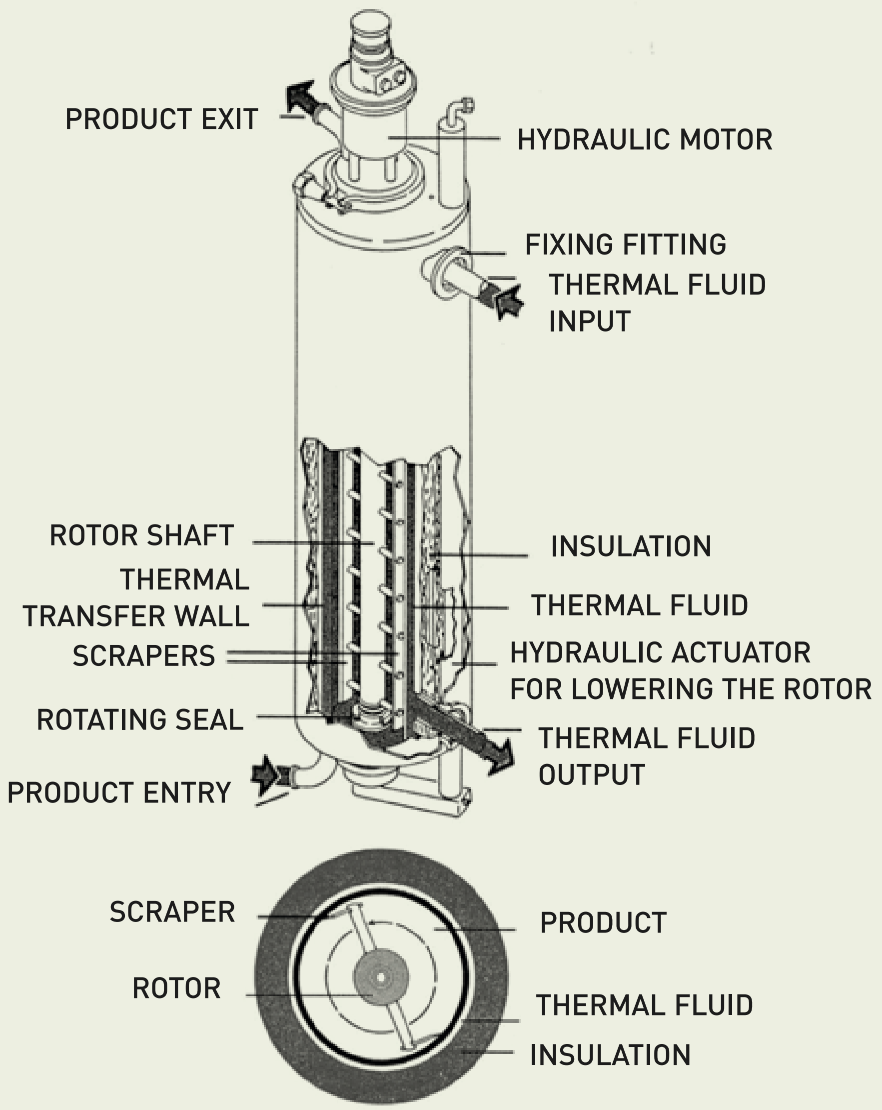
The operating principle is based on the contact between the product and a surface, which has been sufficiently cooled by a cooling liquid.

- **Indirect contact freezers: plate freezers**

The product, packaged or unpackaged, is frozen by contact with a metal surface kept cold by circulation of a cooling fluid (brine, ammonia, Freons, etc.). The advantage of this technique is that there is very little dehydration of the product.

- **Tubular freezers**

These consist of tubular heat exchangers whose internal surface is constantly scraped and cooled by a refrigerant. The product is only frozen until a pastry consistency is achieved, so that it can be pumped and packaged, after which further cooling completes the hardening.



Exploded view and cross section of a scraped surface heat exchanger (source: Alfa Laval)

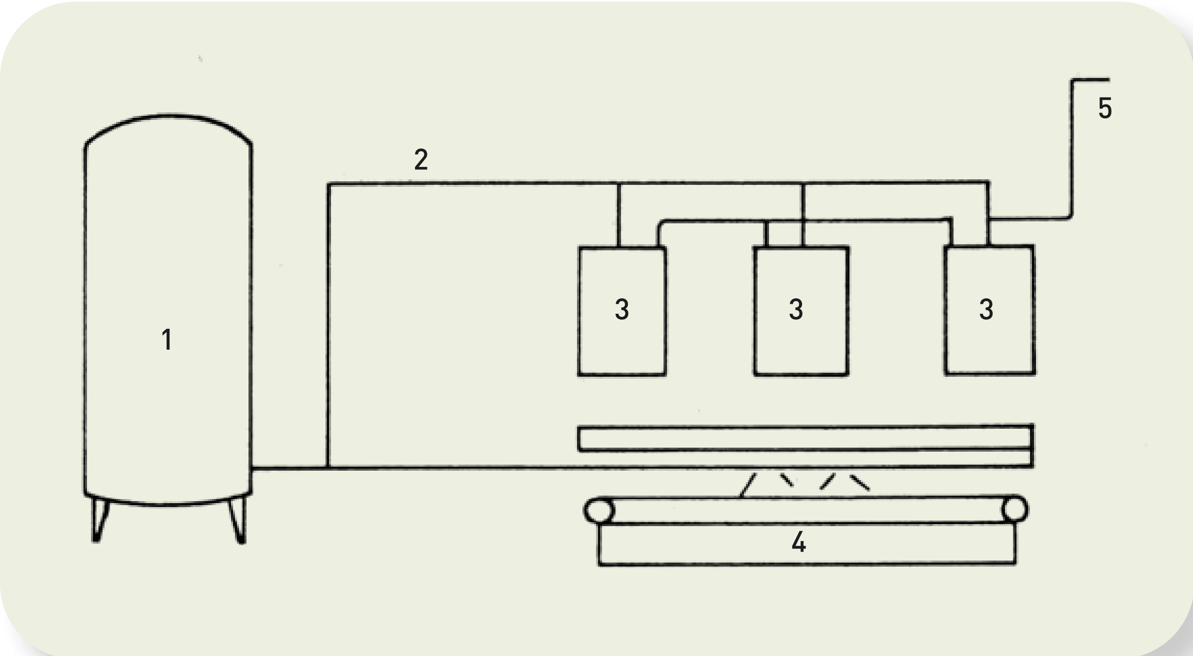
8.4.4.3. Cryogenic freezing processes

Cryogenic (or direct) freezing involves **placing the product directly in contact with a cold source, by spraying a liquid**, such as liquid nitrogen or liquid CO_2, which evaporates on contact with the product. The cooling process is intense due to the high heat transfer coefficients and the possibility of using very low temperatures: -196°C for liquid nitrogen. In this case, the refrigeration input is provided by the latent heat of evaporation of the liquid in contact with the product (liquid nitrogen evaporates at -196°C and liquid CO_2 evaporates at -54°C). Due to contact with the food, the fluid must exhibit various properties: absence of toxicity, absence of odour and flavour, low penetration into the food, no reactivity with the latter, low viscosity, high heat capacity, low corrosiveness to devices.

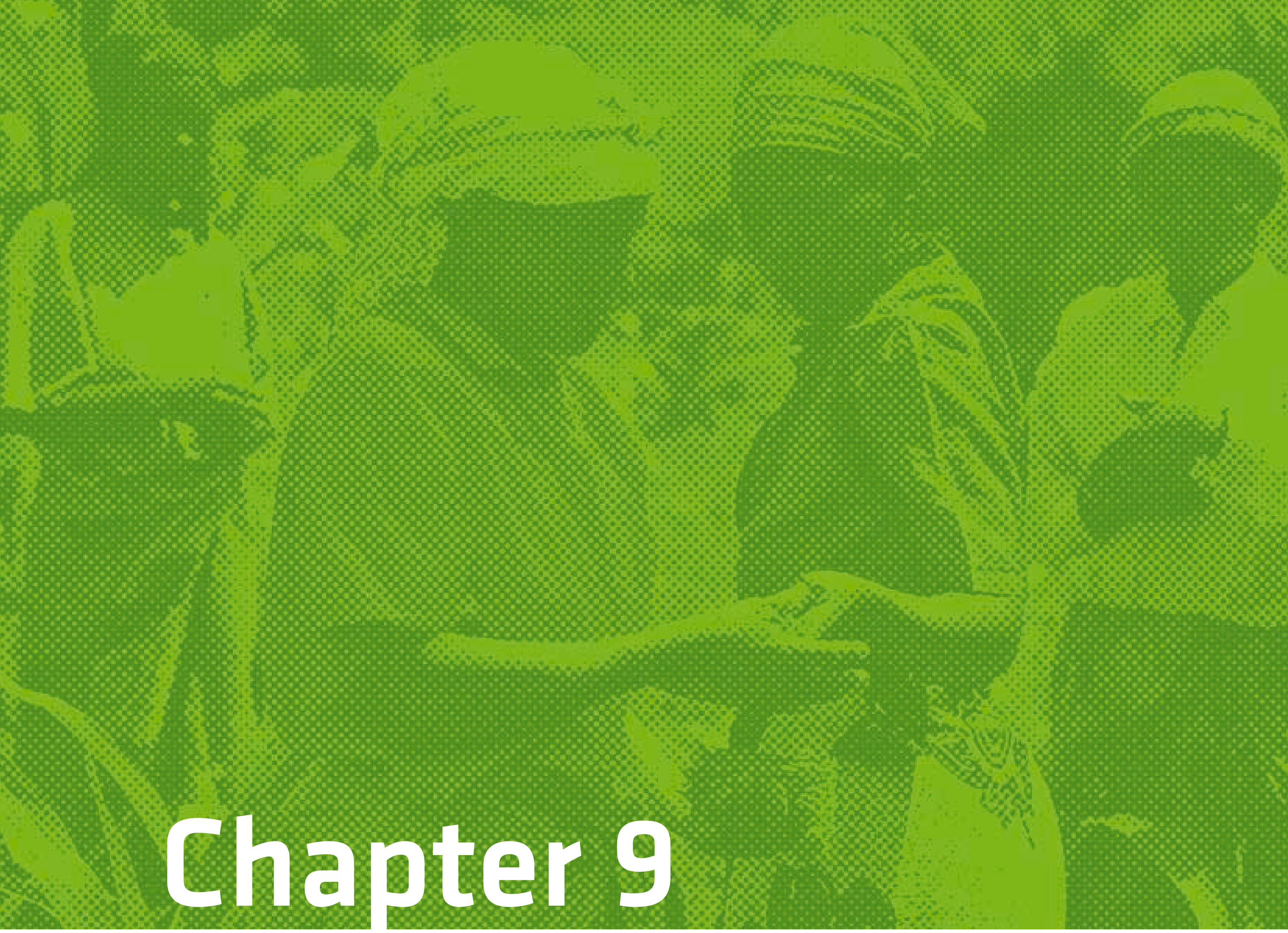
This freezing system has the advantage of being fast, reducing weight loss and in addition, does not require an actual refrigeration unit. However, it is quite expensive and can therefore only be used for food products with a high market value. The technique also makes it possible to obtain frozen products individually (without sticking) or via the IQF process (Individually Quick Frozen).

Deep-freezers consist of a tunnel where the gas is vaporised through spray nozzles fitted with solenoid valves, controlled by a thermostat. A fan allows the distribution of the fluid to be homogenised.

Due to the high cost of operation (high gas consumption, 1 to 1.5 kg of CO_2 or 1 to 1.5 l of nitrogen per kg of frozen product), this is mainly used for products under development or for fragile products with significant added value.



Operating principle of a cryogenic freezer:
1. Liquid nitrogen storage; 2. Temperature feed; 3. Cabinet freezers;
4. Freezing tunnel; 5. Discharge pipe



Chapter 9

Product packing and marking

9.1. PACKING

9.1.1. Definition and regulatory framework

There are several elements involved in packing fresh or processed food products.

1. **A set of individual operations** carried out in post-production or after processing, either manually or within a (semi-)automated packing sequence depending on the volumes, to facilitate product storage, transportation and distribution, and place items on the market for sale (e.g. on display in supermarkets).

   All these operations, from the simplest to the most sophisticated, and depending on the situation and the size of the company, may be carried out on the source farm (where the product is harvested), or in fruit and vegetable packing stations, in a workshop or factory, in cooperatives or in purchasing alliances.

2. **The packaging**; this serves to contain the food products and protect them from contamination, loss or damage, for example caused by impacts, squashing, pests or simply the conditions the products are in (temperature, relative humidity of the air, even odours present in the air).

   The packaging materials must **offer effective protection** of the products, to prevent damage and to minimise spoilage and/or contamination; they must also **enable suitable labelling** to be applied. The packaging materials and, where applicable, the gases used for packing purposes, must neither be toxic nor present a risk to safety (e.g. avoid migration of chemicals into the packaged product) and/or to the wholesome nature of the food (e.g. ensure hygiene), under the stipulated warehousing and usage conditions.

   Packaging may be single-use (recyclable or not) or reusable, but in the latter case it must be sufficiently durable, and easy to clean and (if necessary) disinfect.

3. **Product marking**, which includes "labelling", enables a product to be identified and provides information for the consumer. It is therefore the "identity card" for a product.

   Marking has two components (general information, nutritional information) and **includes a number of mandatory statements**; these are necessary in order to meet marketing standards, which clearly state the regulatory requirements on marking. The applicable marketing standards depend on the plant-based product (the variety). The majority of fruit and vegetables are subject either to the **general marketing standard**, a **specific standard**, or a **particular standard** (e.g. potatoes). Different standards exist: UN-ECE standards and the *Codex* standard for the variety in question; in the absence of standards, special provisions shall apply, notably compliance with ministerial decrees or orders.

   The label, placed on the packaging, enables "traceability" of products (thanks to the lot number in particular; also the barcode, etc.) and conveys a great deal of information, some of which is mandatory. However, information affixed to food products must not be misleading for consumers. It must be accurate, clear and easily understood.

   For this reason, there is usually **an official inspection** of product labels by the appropriate authorities.

The packing, packaging and marking of fresh or processed fruit and vegetables **are closely linked**. Selecting a packing process effectively imposes the options for suitable food packaging, and vice versa, in order to ensure that the container is compatible with its contents, and the packaged fruit or vegetables are conserved correctly. Packaging/packing remains an essential link in the production chain between the raw product and the end consumer.

Regulations – international and national – provide a framework for packing; they impose rules, standards and directives[55] that go further than meeting food hygiene and safety requirements. Here are some examples:

- the General Standard for the Labelling of Pre-packaged Foods (*Codex* STAN 1-1985);
- Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (CXG 32-1999);
- Guidelines on Nutrition Labelling (CXG 2-1985).

It is also advisable to refer to *Food Labelling (Codex Alimentarius)* (5th edition, 2007), and for products shipped to countries in the European Union, refer to Regulation (EU) No. 1169/2011 on the provision of food information to consumers.

We will now examine each of these three aspects in turn: first, the packing process; second, the various kinds of packaging, with their respective properties and advantages for fresh or processed products; lastly, we will take a more in-depth look at food product marking and labelling[56].

9.1.2. Functions of packing

According to the FAO, packing fulfils some essential technical functions (logistics and protection) and commercial functions (information and marketing). There are also other distinct functions, as follows.

9.1.2.1. Traditional functions

- Logistical function: to do with containing, transporting and selling the product. Packaging must facilitate the operations involved in handling, storing, transporting and distributing goods.
- Protective function: packaging must protect the product it contains, the consumer/user who will receive the item and the environment where it will be used. Examples include bottles, food cans, etc.
- Information function: packaging must provide the answers to all foreseeable questions about **the product's origin, composition, handling, transportation and use**. This is why **different types of marking** are found on packaging, conveying commercial and safety information, plus instructions for use and the compulsory legal information.

55 Visit: http://www.fao.org/3/a1389e/a1389e00.pdf, and http://www.fao.org/fao-who-codexalimentarius/codex-texts/list-standards/en/

56 See also the COLEACP manual on product traceability.

- Marketing function: the packaging, as the sole link between the consumer/ user and the manufacturer, has to attract the customer and elicit their interest in the product. The "sales" function (marketing) presupposes five functions: alerting, allocation, service, information and positioning.

9.1.2.2. Modern functions

- A regulatory function, via the freedom of choice that labelling must offer consumers, and the obligations it places on the producer and the retailer for the various situations in which the products are consumed and circulated freely.
- An economic and ecological function relating to the second life of the packaging after use: reuse and refilling, or extracting additional value by recycling the materials and/or burning for heat recovery. The value-extraction function is the priority option for industrialised countries.

9.1.3. Problems related to packing

To consider all aspects, we must remember that development of packaging also poses environmental problems, with reference to the products' life cycle analysis (LCA). These may include:

- recycling (of metal, plastic, paper, cardboard),
- reuse of packaging (e.g. if food packaging is subsequently used as a container for pesticides, there is a clear risk that mix-ups could lead to accidents),
- aspects related to the biodegradability of packaging,
- themes linked to educating people about recycling and making it common practice.

9.2. PACKING FACILITIES

The facilities available must be appropriate for the product volume, in order for packing operations to take place in good conditions (of hygiene/health and safety). The size and design of the packaging workshop, and the equipment and facilities it is to offer, will depend on the nature of the product, the volume, the market requirements, local infrastructures, the estimated cost and the anticipated lifetime of the workshop.

9.2.1. Packing facilities for (small or very small) artisan companies

Insofar as the company continues to produce at artisan scale, with a small volume intended for the local market, simple and clean premises are sufficient. The crucial point in this kind of rudimentary setup (more closely tied to kitchens than to workshops) is hygiene management. This aspect is often haphazard owing to a lack of information, resources and discipline by the personnel. **It is very difficult to avoid product losses and ensure basic hygiene in spaces that are cramped, poorly designed for the purpose and poorly lit, with hard-to clean floor and walls**.

Two examples of rudimentary installations observed in very small companies (photos by B. Schiffers)

When a company has insufficient space, it is not unusual to see activities spill outdoors, with all the risks that this implies for the products (photo by B. Schiffers)

For this kind of company, the construction materials and the building type will depend on the products to be handled, anticipated volumes, the market to be served and access to finance. **Small-scale operations may be able to manage with relatively simple and inexpensive buildings.** However, several conditions will still have to be met:

- Good protection from sun and rain, through having a very large roof that overhangs the walls by at least one metre on all sides;
- Good ventilation, but also protection from squally rain and dust; this balance will usually involve walls that let air through sparingly into a sufficiently large space under the roof;
- A flat, hard floor, enabling easy and safe movement of people and products.

However, there is also no point in over-sizing the packing facilities, especially if the product is neither overly sensitive to contamination nor particularly perishable (e.g. products that are alcohol-based, very high in salt or sugar, or dry). A timber structure with corrugated metal roof and walls may suffice (ensure good ventilation, to avoid heat build-up under the roof!).

9.2.2. Packing facilities for large companies

If facilities are to be large, the choice of site is also important. According to the FAO, the site must meet the following criteria as a minimum:

- The terrain must be flat, and sheltered from strong winds if possible;
- If the packaging premises are to be permanent, they must allow the option of expansion if this becomes necessary;
- Plans should include an area large enough to accommodate the movements and parking of all vehicles expected on-site at peak times. Access roads must be at least 3.5 m wide;
- The drainage system must have sufficient capacity to ensure that rainwater and water intended for the packaging operations can escape;
- The site must be amenable to security measures, for example fences and security guards.

Before selecting where to base the business, it is wise to check the quality of the water that will be used to wash the products, especially if it is drawn from rivers or lakes. This is to make sure it is not polluted by sewage, industrial effluents, pesticides, herbicides or fertiliser.

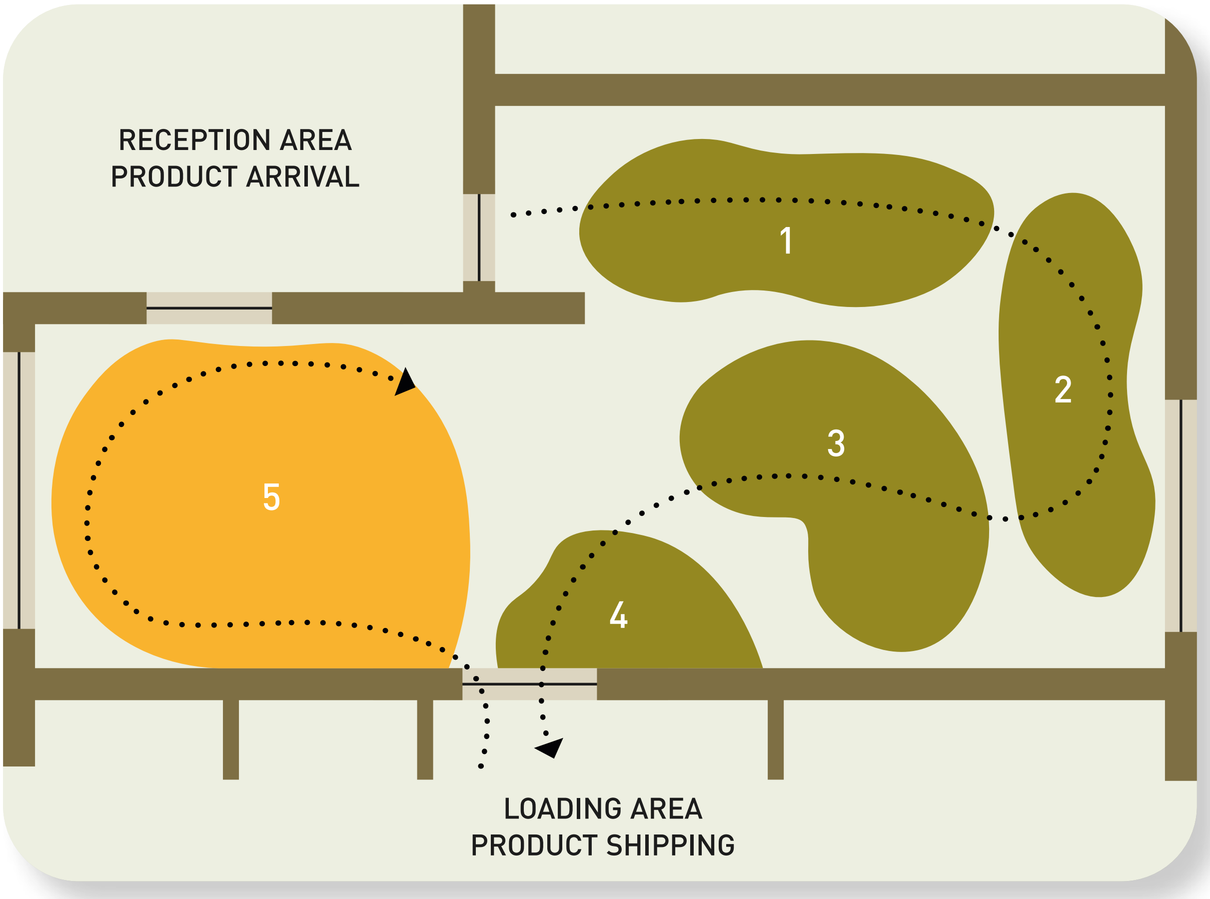
When the business grows, the packing workshop must be carefully considered, and its layout well organised into different work zones. Here are some examples.

- **A receiving zone**, organised such that the products undergo the various packaging operations in the order they arrived: first in = first out. This zone is used for product receipt, sorting and cleaning, including washing where applicable. One must be prepared for this area to become soiled with earth, dust and decomposing plant matter. In order to work well, it should be separated (e.g. using doors) from other activities, to minimise contamination of products that have been cleaned, sorted and packed.
- **An area for storing empty packaging** (cardboard boxes), to keep these items dry and protected from dust, bird droppings and pests in general.

Example of a cardboard box storage area (photo by B. Schiffers)

- **A packaging and marking zone.** This will include special treatment facilities, including installations for drying washed and/or treated products. The main activity will be packaging cleaned products, using sorting and grading equipment if necessary.
- **A zone for checking** products before storage and shipment.
- **A packaged product storage zone.** The packaged products will be protected from sun and rain, *i.e.* heat and water which can cause rapid product spoilage and seriously damage the packaging boxes, including detaching the labels.
- **A product loading zone.** This zone must be located near the packaging operations, and must be entirely free of fixed equipment. The area must be spacious enough to allow temporary warehousing of the packaged products, and pose no obstruction to the movements of either products (during handling) or employees. The shipment zone must be clean and have good airflow. If plans include a room due to serve as an office or for quality control, it could be sited in this area.

The space must be arranged thoughtfully, taking care to follow the "Forward Flow Principle". This means that the receiving zone will be on one side and the shipment zone on the other. As such, the product moves through the facilities (generally arranged on a single level per commodity) from dirty areas to progressively cleaner ones.



1: Cleaning/washing - 2: Production/processing - 3: Packaging/marking
4. Checking/storage - 5. Empty, clean packaging/labels; office(s)

Permanent packaging workshops must have slip-resistant concrete floors, with run-off channels to aid cleaning. It would be beneficial to apply a dust-proof treatment to the floor surface.

Example of a huge packing workshop, with cold storage rooms, in Senegal
(photos by B. Schiffers)

9.3. PACKING OPERATIONS

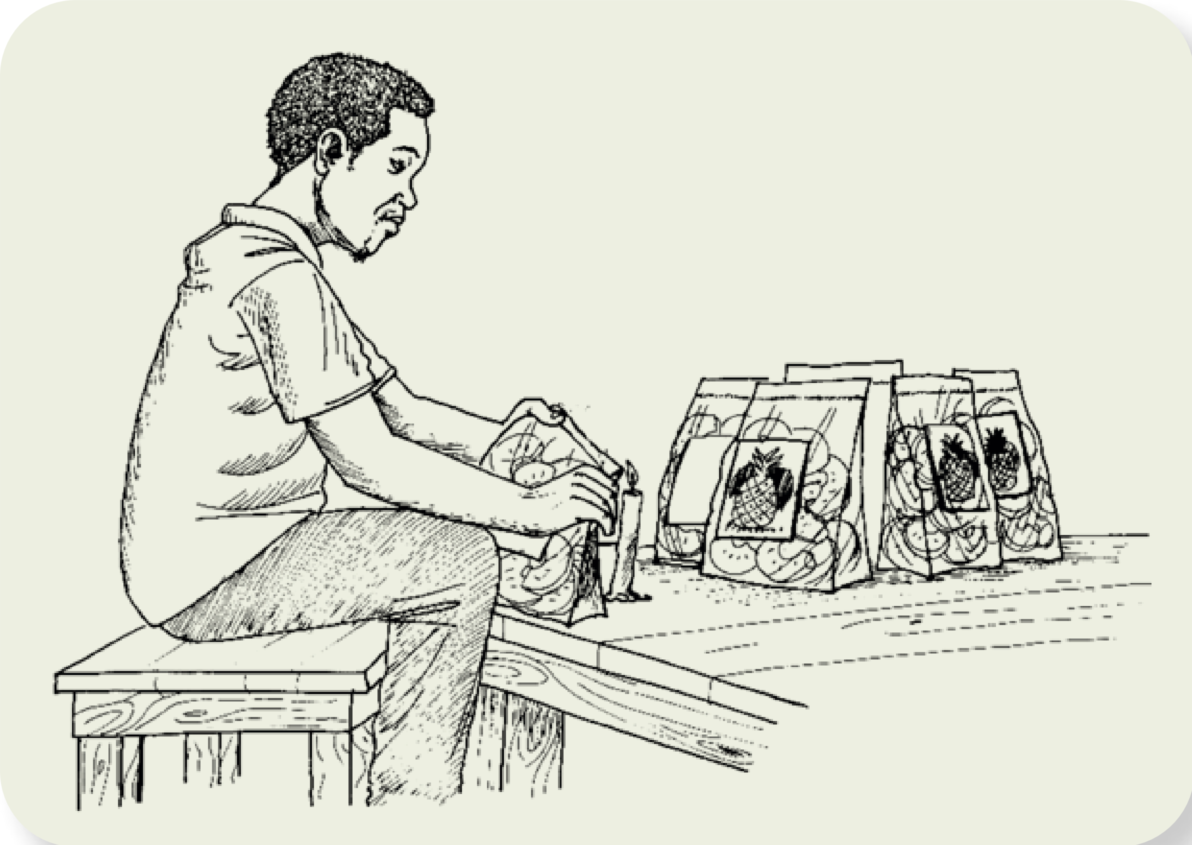
9.3.1. Recap of the main packing operations

An earlier chapter outlined most of the operations that take place after harvesting the product. These operations were also represented in the diagrams showing the production processes for various processed goods (juices, jams, compotes, purées, etc.). Basically, most of these operations have the same objectives and follow the same logic, meaning that they are practically always the same:

- Receipt of lots (=batches) of primary materials: unloading, verification, recording;
- Sorting of products on receipt (to remove unsellable items and foreign bodies such as plant debris, earth or stones) and disposal of waste;
- Cleaning, or sometimes washing (in theory, the latter only if absolutely necessary) followed by draining;
- Submersion in a bath or spraying with an anti-fungal agent (especially if the product will be stored for a long time or shipped far away); Application of wax (or another substance if necessary) to minimise water loss;
- Product selection and grading (sorting according to quality and size);
- Product packaging and labelling;
- Post-packing checks (volume/weight verification; sampling; possibly certification, after phytosanitary treatment where applicable);
- Special treatments on occasion (degreening, *i.e.* using ethylene to trigger ripening);
- Storage and cooling;
- Grouping and preparation for shipment.

9.3.2. Packing very small quantities

In small establishments that do not sell their product in bulk, packing involves **hand-filling the packaging units** in which the product will go on sale. As a lot of products are still bought and sold by weight, the majority of packaging workshops are required to have weighing equipment. There are a number of types of weighing scale (beam balance scale, digital jewellery scale).



Below are the steps involved in packaging and storing of products at small scale, according to Agrodok (CTA, Technical Centre for Agricultural and Rural Cooperation).

- Place the vegetables and dried fruit in their packaging of airtight, waterproof black plastic sachets.
- Seal the bags with a candle flame. Alternatively, use a heat-sealing machine.
- Write on the bags the manufacture date and the product expiry date (six months later).
- Put the bags in a cardboard box so that they will not be affected by the light.
- Store the boxes in a cool, dry place.

9.3.3. Packing operations for fresh fruit and vegetables

Generally, the packing operations for these types of product, sold fresh, are as follows.

- **Unloading the harvest trucks:** standard modules automatically lift piles of full boxes from the harvest trucks, and distribute each one to stations where they are either weighed, automatically graded or palletised.


- **Sorting and weighing station:** lines for sorting, packing and weighing the crates of product. Ergonomics and functionality are the key criteria in designing these stations. They are tailored to the products handled and the desired throughput.

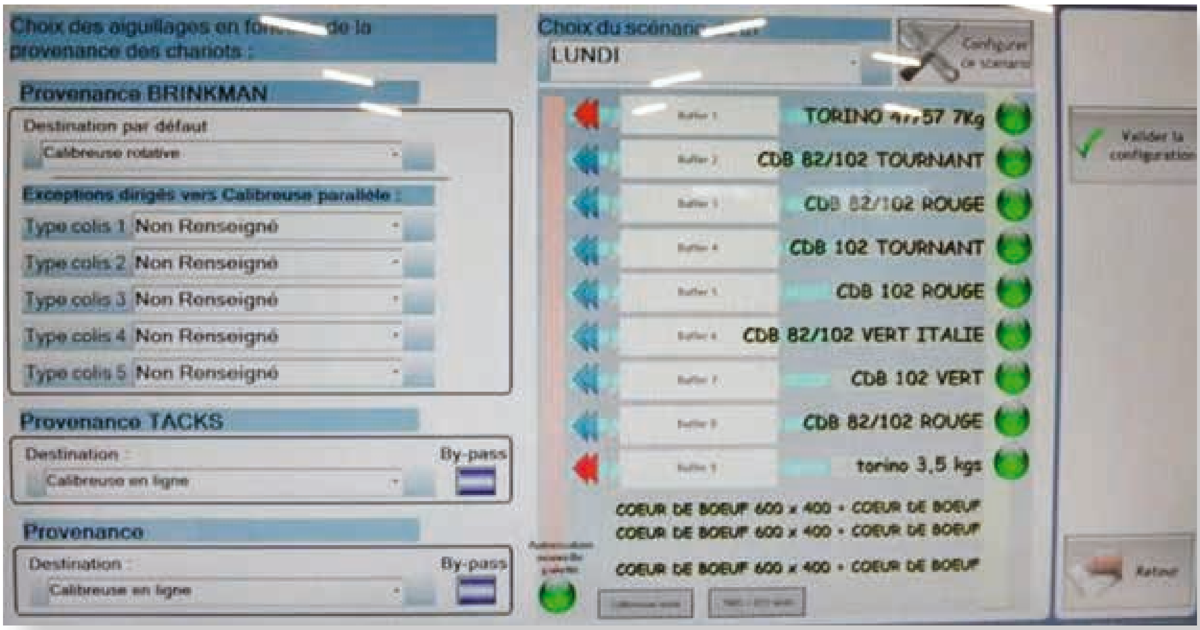

- **Feeding product to automatic size-graders:** product is deposited softly at a set pace, preserving the product's quality and steadily feeding the graders (rotary or roller conveyor). Empty crates are organised with a view to supplying the packaging stations.


- **Checking and sorting packaging (cardboard/wood/plastic box) according to product, calibre and colour:** sensors are used to recognise different calibres and colours of product. This checking system is used to sort products, facilitating their storage or palletisation.

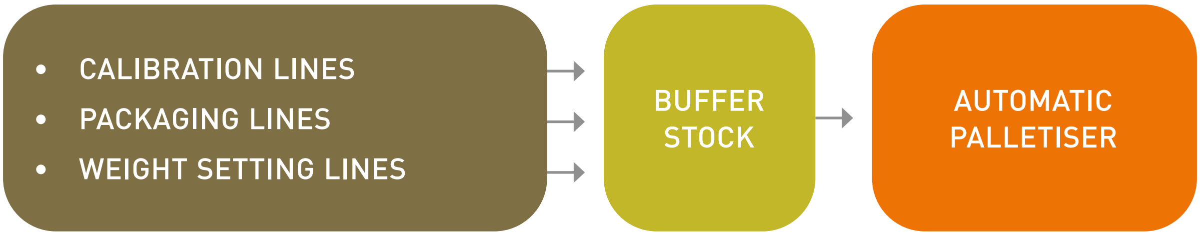

- **Storage before palletisation:** vertical or in-row storage systems help optimise the use of a single automatic palletiser when working with a flow of boxes containing several product references.



- **Automation/monitoring:** the touch-screen monitoring systems associated with machine automation enable the facilities to be controlled and their settings adjusted. Fault diagnosis and mini-management of the workshop's output take place as per the overall packing scheme.



AUTOMATED PACKAGING SCHEME



- **Packing location(s) for fresh fruit and vegetables**
  - **Packing in the field**: as they are harvested, the products are placed straight into crates made of cardboard, plastic or wood. Certain products are packaged separately. If possible, crates or boxes filled this way are then sent to a pre-cooling installation to draw off the warmth of the harvest.

On-site packing, just after picking: sorting
(photo by B. Schiffers)

Packing in the field, in a covered area
(photo by B. Schiffers)

- **In-station packing**: the products are processed or packaged in an enclosed space or in a covered area in a central location. The loose products are transported from the harvesting sites to the packaging station, in slatted cases, vats or trucks. If possible, depending on their nature, the products should be pre-cooled either before or after they are packaged for shipment.

In-station packing

- **Repacking**: products are taken out of their initial packaging, re-graded and placed in different packaging. This is often done to put the items into smaller packaging intended for retailers or consumers.

- **Special treatment after packing**

  Some products undergo special treatments after they are packed and packaged, especially in large companies working to supply urban markets and export. The three main treatments are outlined below.

  - Phytosanitary treatment (e.g. steam treatment, spraying) is intended to combat controlled pest insects such as fruit flies. It is a mandatory condition of import into many countries, and implies the use of special equipment and trained personnel. Note that pallets and packaging made of wood must also be free of pest organisms. These items may be heat-treated before use.
  - Triggering fruit ripening: this takes a few days and implies that the packaged fruit will be treated with ethylene gas in insulated, controlled-atmosphere warehouses. This is a high-cost operation, and therefore only of relevance to large companies.

- Degreening of citrus fruit: brings out the natural colour of citrus fruits. Citrus fruits grown in tropical regions stay green until they are ripe, unless they are subjected to low overnight temperatures. On the other hand, they will take on their normal, natural colour if they are artificially "de-greened" using an ethylene treatment similar to the one used to trigger ripening. Small companies rarely use this treatment.

- **Warehousing of fresh, packed products before shipment**

  Time plays a major role in marketing fresh products. Delays lead to increased losses. Once they are packaged, products must be shipped to their market outlet as quickly as possible. Consequently, managers have to make transport-related provisions a high priority.

  However, in small companies it can take some time to gather a full load; therefore, when a certain amount of time has to be spent preparing packaged products in sufficient number, every effort must be made to prevent them from deteriorating.

  The following points require particular care.

  - The packaged receptacles will be protected from sun and rain; heat and water can cause rapid product spoilage and seriously damage the packaging boxes.
  - The packaged cases must be handled with care when they are stacked, to avoid damaging the contents; damaged contents are liable to lose water and to decompose.
  - Packaged containers awaiting transportation must be stacked in a way that ensures sufficient ventilation; a product that is too warm deteriorates quickly.

  Losses of fresh products during packaging operations can be minimised if the product is:

  - Kept cool as far as possible,
  - Kept dry,
  - Protected from impacts,
  - Swiftly delivered to its market outlets.

9.3.4. Packing operations for processed products

There is no single standard approach to packing processed fruit and vegetables. **Packing is tailored to the type of end product and the packaging used** (food cans, jars, bottles, sachets, etc.). We therefore prefer to describe the packing operations by explaining the different techniques used to process fruit and vegetables.

The packing for each type of product (e.g. solid, semi-liquid, liquid, pasty, powdery, and so on), will employ an **appropriate technology to ensure the nutritional and sensory characteristics and the health status** of the processed fruit and vegetables, from their manufacture until their ultimate use by the consumer.

The initial operations, from receipt until washing, **are usually identical** to those for fresh products. However, there will naturally be no anti-fungal treatment before processing. Next come the processing operations, which vary depending on the product being made, and eventually the product is ready for packing.

Packing after processing, whether at artisan or industrial scale, **usually involves filling various "receptacles"** (e.g. food cans, bottles or jars) with the product, which may be cool, or not (e.g. if it has been heated for pasteurisation). For some products, liquid may be added (for example brine, vinegar, alcohol, syrup).

As such, packing a **liquid foodstuff** is a matter of **collecting a particular quantity of the liquid and putting it in an "enclosure" that will be hermetically sealed after filling**. The receptacles may be:

- Narrow-neck bottles;
- Wide-neck flasks;
- Jars and metal drinks cans;
- Cartons made of composite materials (TetraPak®).

Receptacles are machine-filled using one of two methods: constant-level filling, where the receptacle is in close contact with the filling machine, and the free-jet method which can only be used with plane liquids. For fitting bottle closures, different processes are used, requiring specific profile rings for the receptacles. Crimping to seal metal food cans is a delicate operation that often calls for a different canning-machine design than the one used for bottles.

The risks linked to filling operations **arise particularly from** the following factors.

- **Glass handling.** The risks vary, depending on whether the bottles sent for washing are new or recycled. Risks also depend on the cleaning products (water and detergents) and techniques used (washing by hand, by machine or a combination of both). Further determinants of risk include the shape of the bottle, the filling method (manual or sophisticated, with addition of carbon dioxide), the closure process, the complexity of the system of stacking/packaging in boxes or cases after labelling, and the final tasks performed.
- **Receptacle hygiene.** Receptacles must be clean, and if possible sterilised, before use. This means that washing of bottles or jars employs large machines in which the receptacles are subjected to soaking and successive injections of detergent solutions and water. To rinse, antiseptic solutions and water are injected and then drained off.

9.4. PACKAGING

9.4.1. General points on packaging

Updating and development of packaging products and techniques, which could reduce losses of produced food, are major global challenges because such losses simultaneously affect small food producers on low incomes and consumers living in food insecurity. At global scale, packaging is the third largest sector, with only the food and petrochemicals industries ahead of it. At national level, it is also among the top five sectors in almost all countries, with an annual growth rate of 3-5% (which is higher than nearly all national GDP increases).

The innovations and changes applied today, in response to consumers' evolving preferences and demands, have fleshed out the role of packaging beyond simple protection; its functions now include promotion, information, convenience, education and ergonomic handling.

Packaging is becoming the fifth pillar of marketing (together with product, price, distribution and promotion), particularly because it facilitates branding strategy, while helping to distinguish and identify products, tasks that are easier in the place of purchase.

Baskets, bags or traditional trays are used in most developing countries to transport the produce to market. These receptacles are usually inexpensive and made from readily available materials, for example dry grass or palm/bamboo leaves. Although they are well suited to the task of carrying fresh produce a short distance, **they present a number of drawbacks** when it comes to shipping large loads to far-off places.

The packaging of products shipped in large quantities for wholesale trade must improve, **to reduce losses and ensure that the transport methods are viable**. This means preventing the product from being damaged during handling, transport and storage, and providing receptacles that are easy to handle and count, and of uniform capacity.

The use of standardised packaging avoids having to re-weigh items and may aid handling, stacking and loading. Lots of packaging is made from paper and paper-derived products (e.g. compressed or corrugated card), from wood (= the source of paper) and wood-derived products (wood offcuts, particles e.g. wood flour and sawdust), and from soft or hard plastics. Each type of packaging must be carefully considered as regards its usefulness, cost and subsequent value extraction.

9.4.2. Packaging and loss of food products in the value chains

Packaging is present at every stage of the value chain, and all the trading partners share in the responsibility for it. In developing countries, the biggest product losses occur before and just after harvesting the product, which underlines the need to focus efforts on packaging solutions and on the infrastructures that connect the farms to their markets, essential links in these early stages of the value chain. This situation contrasts sharply with that in industrialised countries, where the largest product losses are observed at the retail sale and consumption stages.

As a general rule, the products are a more precious resource, and have a higher intrinsic value, than the packaging used to protect them. Therefore, product loss caused by inadequate packaging can have a harmful effect on the environment that outweighs any gains made by reducing the amount of packaging.

Knowledge of the nature and extent of product losses, as well as when and how they occur, may help accurately pinpoint the solutions (especially packaging) for reducing the quantities that are lost. To tackle the issue of food product loss, it is also essential to know which packaging solutions already exist or which should be available for use over time.

It is undeniable that in today's world no product, particularly products for consumption, can be distributed without packaging. Packaging materials and the technologies for their application are rapidly expanding in industrialised countries, while developing countries remain outside this progress (4^{th} range: preservation in a controlled atmosphere).

Packaging presents one of the qualitative characteristics, chiefly in the preservation and distribution of products. When we speak of packaging, the idea of packing is implied (there is no packaging without packing). Packaging and packing must be considered as one operation in the manufacturing process. Any project must include it as such, and not as an "afterthought".

9.4.3. Packaging functions

Packaging comes down to placing the product inside a receptacle, where wrapping material will immobilise the product (tray made of plastic or papier mâché; inserted pieces, padding, etc.) and protect it (plastic film, wax lining, etc.). Packaging is intended to meet **three basic objectives**:

- **contain the product, rendering it easy to handle and put on sale** by establishing standards regarding the number of units/weight of each packaged item, and by improving the product's presentation;
- **protect the product and goods against external hazards:** climatic (temperature, RH, UV, drop in pressure), physical (impacts, falls, vibrations, etc.), animal action (rodents, insects, etc.), germs and other micro-organisms, odours (an issue in greengrocers' shops), theft ("manumission": term used to indicate the possibility of theft); bruising (due to impacts, compression, rubbing and damage) during transport, storage and placing on sale;
- **provide the customer with information** on the product variety, weight, quantity, selection method or quality/grade; also the producer's name, the country and/or region of origin, etc. It is also common practice for the packaging to include recipes, details of nutritional value, product barcodes or any other information that may help someone trace where it came from.

There is enormous variety in packaging and the materials that comprise it. At present, technology can address the concerns of those who package products, if the characteristics of the product, its shelf life, and the system used for handling, storage and distribution are known. In response to these concerns, quality can be improved by drawing up product specifications, adopting standards and – better still – introducing regulations (on health, hygiene and safety).

A well designed "pack" will necessarily suit the conditions or specific processing of the product. For example, if the pack must be cooled using water or ice, it must be able to withstand moisture without losing effectiveness. Products that have a high respiration rate require packaging with large enough openings to enable sufficient gas exchange. For products that dry out easily, the pack will be designed to provide an effective barrier against water loss, etc. Semi-permeable materials can be used to create a special atmosphere inside the packs, helping to maintain product freshness.

9.4.4. Packaging trends and development outlook

The global food system is currently undergoing many changes in the way food items are produced, distributed, stored, processed and sold. On the one hand, this increased dynamism in the food system throws up multiple challenges for the packaging sector, but on the other, it opens up outlets and opportunities that should enable the packaging sector to develop and prevail.

The fact that we are turning towards local processing of traditionally exported products, and introducing new packaged consumables from developing countries onto the global market, together mean that exporters in these countries of origin will need in-depth understanding of the demands of consumers in industrialised countries. These changes will bring their own set of challenges, because exporters in developing countries will have to sell their products directly to consumers in their target markets, operate under their own brand name, remain competitive in their packaging creation and maintain a high level of quality. These issues will not be exclusive to the exporters; they will also affect the packaging sector in the developing countries concerned.

In developing countries, the general tendency for packaging manufacturers to **approach their clients** opens multiple possibilities for investment in this sector. The interest generated on Northern and Western markets by the exoticism of products, particularly fruit and vegetables, from developing countries in the global South should be extended to the product packaging. The relative fragility and fairly short shelf life of local materials generally limit their use as primary materials in packaging. However, innovative exploration of using them in combination with other materials, assisted by research and technological advances, offers a promising investment domain.

Standardisation of containers is a cost-reducing strategy and has given rise to a wide range of packaging formats to meet the diverse needs of wholesalers, consumers, buyers for catering services and processing companies.

Across the three branches of the sector, packaging manufacture opens up more prospects than machines or services in developing countries. The main explanation for this is that the packaging machinery branch is strongly dominated by developed countries. In the short and medium term, it would be useful to study outlets that have a buoyant market of second-hand machines. However, in the long term, it would be more beneficial for developing countries to look into the possibilities offered by local production of simple packaging machines, tailored to their needs and requirements. The expansion of the packaging services branch, notably pre-packaging and outsourcing services, will provide much-needed stimulation for the food packaging sector in developing countries. These services will drive down the cost of packaging and packing, making both more affordable, and will also enable exporters (especially SMEs) to make efficiency gains in their handling and distribution.

Given the **shortage of packaging materials in developing countries**, it could certainly help the sector if the packaging regulations could be softened slightly without sacrificing food safety. For example, the use of recycled packaging materials could be authorised when said materials pose no risk of contaminating the food (as with dehydrated food items). This kind of relaxation of the packaging standards would help increase the quantity and range of packaging materials, and at the same time contribute to solving food product loss issues.

9.4.5. Factors that determine the choice of packaging

Selecting the best packaging for a given product aims to reduce costs, both direct (purchase of materials, waste management) and indirect (packaging process, handling, storage and losses due to damage).

Below are the main aspects that determine which of the different packaging types to choose.

- The product characteristics, for example its state (liquid, solid, gas), weight and volume; its fragility, stability (whether it loses its shape or stays rigid); whether it is perishable, the degree of hazard it poses and its monetary value.
- The process of production and packaging will determine the type of primary and secondary packaging to use. Manually applied packaging formats are different from automatically applied types.
- Handling during transport and storage: many aspects must be taken into account, such as the stacking height that the packaging must support, the storage duration, the different transport methods used by the company (some of which cause vibrations that affect the product), the number of times packed items will be loaded and unloaded, the relationship with reverse logistics (for example some types of secondary packaging are prepared with a view to return to the supplier, and reuse), and the temperature and humidity the product will be subjected to during transport and storage operations.
- The environmental impact of the packaging waste and the options for recycling or reuse.

- The point of sale: essential considerations are the display location in the shop and the handling required for the POS. Furthermore, in the case of online sales, it is wise to give some thought to the moment of unpacking, or the box itself, since this is the customer's first physical contact with the brand and the product.
- The laws and regulations that govern the packaging characteristics; for example, technical standards (e.g. from the EU or ISO), and international transport regulations such as the International Standards for Phytosanitary Measures No. 15 (ISPM 15).

9.4.6. Packaging levels

There are two types of classification applicable to packaging function. However, the principles developed by these two types of classification converge in their vision. A product's packing comprises several layers of packaging. They are defined as follows, according to EU directive 94/62/EC.

9.4.6.1. Primary packaging, sale packaging or unit of consumption

The **primary packaging** contains and protects the product. It is in direct contact with the food item and must maintain said item in optimal conditions. This packaging demarcates the smallest unit of consumption and enables the product to be sold as individual items. It takes various forms: food cans, pots, bags, bottles, etc.

The functions of primary packaging are to:

- **state the nature of the product** as per the applicable standards, and convey information about its use, plus other essential data such as the expiry date;
- depending on the product, it must also fulfil the important role of **naming the brand** and increasing the appeal for the consumer;
- ensure that the product **remains stable on the sale shelf** in the shop (*i.e.* does not fall);
- **isolate the contents** from their environment;
- protect the product using **minimal materials**.

Primary packaging (avocados, mango juice and dried mango/pineapple are all in direct contact with their packaging)

9.4.6.2. Secondary or grouped packaging

Secondary packaging is a unit formed of a group of items in primary packaging. It offers greater protection and enables the product to be made available for sale on a larger scale. It chiefly consists of cardboard boxes, although they may equally be made of plastic. For example, in the case of Dafani mango juice from Burkina Faso, a one-litre carton of Dafani juice would be the primary packaging, and the cardboard box containing the pack of six one-litre cartons would be the secondary packaging.

The functions of secondary packaging are to:

- Withstand stacking (in the warehouse and at the point of sale) and handling during transport, so that the product will not be damaged;
- Contain a set quantity of product(s);
- Attract the customer's attention, especially for items intended to be sold directly to the public in their secondary packaging.

Secondary packaging: 6 bottles of mango juice
constitute one retail sale unit

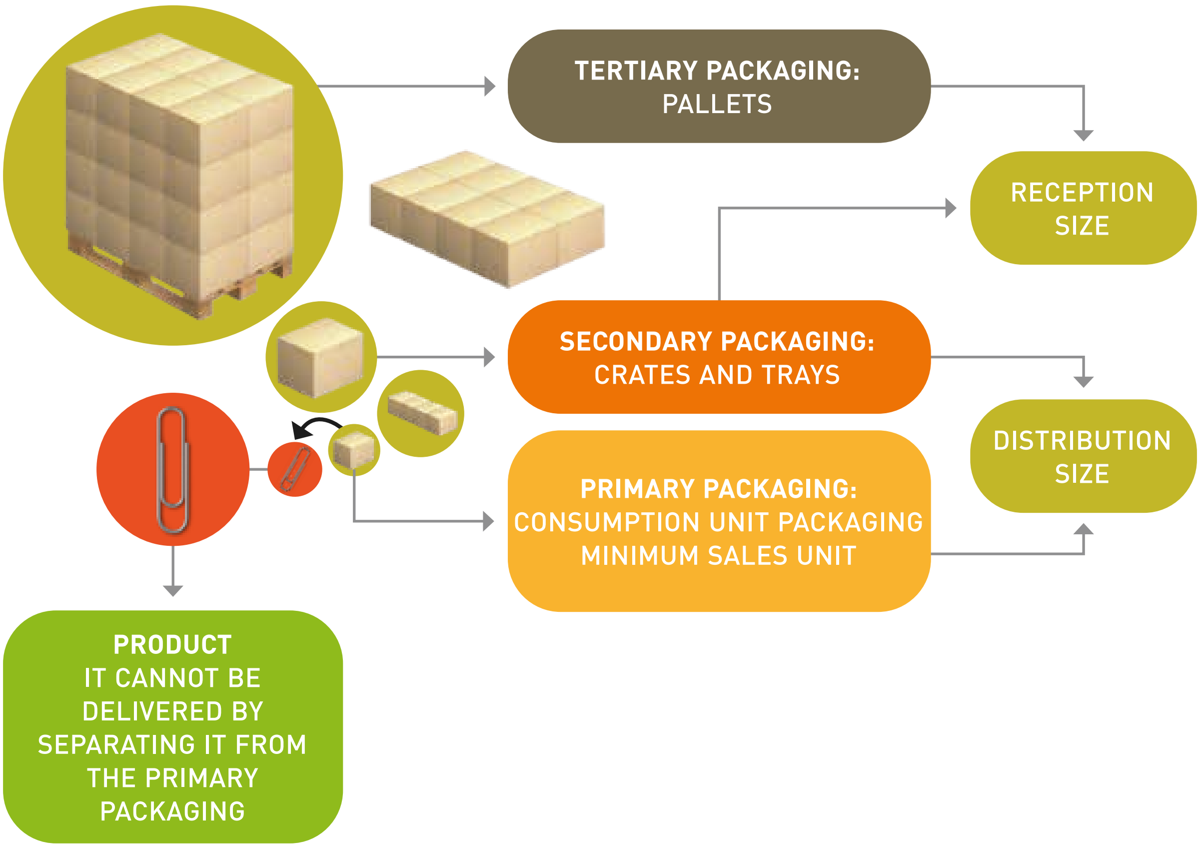
9.4.6.3. Tertiary packaging

Tertiary packaging groups primary and secondary packaging together to create a larger unit for loading; the most frequently used form is a pallet or bulk container, and the modular cardboard boxes comprising the load.

The functions and characteristics of tertiary packaging are:

- To be stable and allow **load compaction**;
- **To take maximum advantage of the storage capacity** of the industrial vehicles and installations;
- **to be approved** and manufactured from tough materials;
- To play an important role in terms of **brand image**; we underline the example of e-commerce logistics, where the case or packaging used for transport falls under the tertiary type and may **include visuals of the brand.**

In this context of logistics, it is a good time to recap the role of the loading unit. This is the basic unit that the company uses to transport and store its products. It may be pallets, cases, containers, jerrycans, reels, large containers for loose products, bags or "Big Bags", etc. Different loading units may be kept in the same storage facility; they are distinguished from each other using zones and different types of racking based on what is most suitable for each unit type.



Primary, secondary and tertiary packaging structures

9.4.7. Types of packaging for fresh products

We distinguish between the following types of packaging.

- Volumetric filling: products are placed manually or mechanically into their packaging until the desired capacity, weight or number of units is reached.
- Trays or honeycomb-design modules: products are placed in trays or "cell" spaces that keep them separate and reduce the risk of bruising.
- Direct packaging: products are carefully placed in the packaging. This reduces the risk of bruising and makes the products look appealing.
- Unit packaged for individual sale, or pre-packaging: relatively small quantities of product are packaged, weighed and labelled for retail sale. When the weighed product reaches the consumer in the same packaging as that in which it was prepared, it is called a consumer unit or pre-packed. The materials used include papier mâché or polystyrene trays in shrink wrapping, plastic or paper bags, individual moulded hollows, thermoformed PVC trays, etc. Onions, potatoes and sweet potatoes are sold in net bags containing 3 to 5 kg of product.
- Packaging under clear plastic film or shrink-wrap: each fruit or vegetable is individually wrapped and sealed in an airtight film to reduce evaporation and decomposition. The film may be treated with fungicides or other authorised/approved chemicals.

9.4.8. Modified atmosphere packaging

9.4.8.1. Principle

Packaging can also be used to **modify the atmosphere around the product**: for example, **reducing the oxygen concentration and increasing the quantity of carbon dioxide** (oxygen content is lowered to around 10%; CO_2 content is increased to around 1%). This reduces the product's respiration and slows ripening. Modified atmosphere packaging is therefore a technique that involves changing the atmosphere surrounding the food product and **thereby controlling the chemical, enzymatic and/or microbial reactions** so as to eliminate or reduce the main kinds of spoilage. It is a "gentle" preservation technique; it uses no thermal or chemical treatment on the food product but is aimed at extending the item's shelf life while maintaining its quality.

Different gases are used in the food sector (nitrogen + carbon dioxide, argon, helium, nitrous oxide, even hydrogen or oxygen), but we are only interested in two:

- CO_2 (E 290), which acts (through oxygen deprivation) on the phenomena of oxidation and the growth of bacteria, mould and yeast, at enzyme reaction level;
- Nitrogen (E 941), which also takes effect through oxygen deprivation, and is used chiefly to guard against product crushing.

9.4.8.2. Fourth range products

Fourth range fruit and vegetables are **raw, fresh products packaged for consumption in domestic or public contexts, and ready for use** having undergone one or more preparations such as peeling, chopping or some other action (e.g. ready-for-use salad leaves, grated carrots, diced vegetables for making soup, etc.). They are generally packed in **plastic packaging** (polyethylene, polypropylene, composite films, etc.) that helps retain a modified atmosphere during the period prior to consumption. The film used must be heat-weldable and of suitable permeability.

Regulations require these fourth range products to be kept at 4°C. In these conditions, the product's shelf life is about a week. Modified atmosphere packaging for fourth range products always goes hand in hand with very high relative humidity, which minimises product dehydration but favours the proliferation of phytopathogenic micro-organisms, which include bacteria, yeast and mould. To ensure **better microbiological stability**, one permitted process is disinfection using hypochlorite (maintaining the concentration of active chlorine between 50 and 100 ppm for one minute, and pH below 8, followed by rinsing).

As regards pathogenic germs, legislation requires checking for the presence of *Salmonella* and *Listeria monocytogenes*. The products in question, being fairly nutrient-poor, are not good support media for these germs. In addition, a significantly large presence of phytopathogenic bacteria would damage the product's commercial reputation, possibly leading to the emergence of human pathogens. The risk to the consumer is therefore very low.

Similarly, for products affected by enzymatic browning, **additives must be used** (ascorbic acid, citric acid, sodium metabisulphite).

9.4.9. Standardisation of packaging

Since the packaging used varies widely in size, the use of standardised packaging is desirable. Standard-size packaging:

- Enables maximum use of the loading surface of standard pallets, with other packaging; there will be no overhang, and items will be set back only slightly;
- Ensures that single-unit loads, and also mixed loads, are stable on pallets;
- Reduces the costs of transportation and commercialisation.

One of the biggest advantages of standardised measurements is the use of space they enable at all stages in the supply chain, from production, through storage, to transport. Hence the potential benefit of using pallets more widely as a basic tertiary packaging format for load compaction in ACP countries.

Packages for shipment must be appropriately sized and filled to a suitable level. Very large packages, **for example, weighing more than 23 kg**, increase the risks of rough handling, and of damage to the product and its packaging.

Over-filling damages the product and causes the sides of the packaging to bulge excessively, which reduces the compression strength and solidity of the packaging. Under-filling also risks damaging the product. The product will be bruised if it slides around in the packaging during transport and handling.

9.5. PACKAGING MATERIALS

9.5.1. Packaging intended to preserve the quality of fresh fruit and vegetables during transportation and placement on sale

9.5.1.1. Necessities

The packaging must be able to withstand:

- a lack of care taken during loading and unloading;
- pressure from the weight of other packages piled on top of it;
- impacts and vibrations during transport;
- high humidity during pre-cooling, transport and warehousing.

9.5.1.2. Packaging materials

The packaging materials are chosen based on the product's specific characteristics, the packaging method, the pre-cooling method, strength, cost, availability, the purchaser's requirements and freight charges. Packaging importers, purchasers and manufacturers are able to provide useful recommendations.

The main materials used are:

- Cardboard: deep bin-type boxes, glued/stapled/slot-fitted boxes, lugs, trays, flat boxes, interior construction and separators, panels;
- Wood: pallet crates, cleated/nailed boxes, baskets, trays, lugs, pallets;
- Paper: bags, sleeves, envelopes, linings, void fill padding and/or shredded paper, and labels;
- Plastic: deep bin-type vessels, boxes, trays, bags (mesh, a single piece), containers, sleeves, transparent film packaging, linings, separators and panels;
- Honeycomb plastic: boxes, trays, lugs, sleeves, linings, separators and padding.

Using different packaging materials for different fruits

9.5.1.3. Shipment packaging

We consider crates/pallets, boxes, trays, lugs, baskets and bags to be shipment packaging. However, baskets are difficult to work with in mixed loads also containing right-angled boxes. Bags, on another note, offer only limited protection to the products they contain. The cardboard box is a widely used form of packaging.

Some examples of its presentation are:

- Single-piece box with flaps either glued, stapled or folded down;
- Two-piece box with a lid; two-piece box with a slot-in lid and reinforced corners;
- Three-piece Bliss-type box with stapled or glued bottom and reinforced corners; single-piece box with a slot-in lid;
- Two-piece box, pressure moulded with a slot-in lid; single-piece box with wire-stitched sides or ends;
- Stiff cardboard with plastic base, providing stacking strength and aiding alignment.

Cardboard boxes intended to receive products that will be packed wet, or with ice, must have an internal coating of wax or another water-resistant material. The crushing resistance of untreated cardboard can drop by more than half if the relative humidity reaches 90%. As well as boosting the stiffness of the box, wax reduces the amount of humidity lost from the product to the cardboard. In all boxes whose cardboard is glued, the adhesive must be water-resistant.

Most cases made of cardboard or wood are designed to be stacked base to lid. Stacking boxes or cases on their side wall or end may compromise crushing resistance and product protection if the loads are large. If cases or boxes are not aligned, they can lose up to 50% of their crushing resistance.

Illustration of fruit packaging boxes stacked on side walls and on lids

Various materials are added to shipment packaging, to make it more rigid and improve protection of the product. Partitions or compartments, as well as double- or triple-thickness sides and base, render packaging boxes more resistant to crushing and reduce damage to the products. Bruising of fruit and vegetables can also be avoided by using padding, cushioned envelopes, sleeves and shredded paper fill.

Pads are also used; they can **keep products moist**, as with asparagus; they can also deliver chemical treatment against decomposition, for example a sulphur dioxide generator pad in packs of grapes, or pads of potassium permanganate can be used to absorb ethylene in boxes of bananas or flowers.

We use **plastic films or bags to retain moisture**. For most products, **perforated plastic** is chosen as it allows gas exchange and avoids excess humidity. On the other hand, **non-perforated plastic** is used when products are to be kept not in normal air but **in a modified atmosphere, by reducing the amount of oxygen available** for respiration and ripening. This is the process used, for example, for bananas, strawberries, tomatoes and citrus fruit.

9.5.2. Packaging of processed products

9.5.2.1. Benefit

In our modern society, processed fruit and vegetables could not be distributed without packaging that is not only practical for transporting and using the product, but also protects and preserves it effectively. Fruit juices, whether 100% fruit or drinks with sweeteners and water, obviously have to be in a pack before they can be transported! Their packaging also ensures that they are preserved well over time without detracting from food safety, flavour and nutrition.

However, **packaging also serves as a communication medium**: it offers a way to capture the consumer's attention and provide information (particularly the ingredients, advice on conserving the product, etc.). Whether it is for dried fruit, jam, fruit juices/ fruit drinks or any other product, the choice of packaging is therefore a strategic one combining technological performance with aesthetic appeal.

Although this is well known, it is important to restate that a range of different packaging types are used to hold fruit juices: plastic, cardboard and glass (metal cans are very rarely used). These containers are infinitely modifiable and customisable in shape, design and size... so everyone can find one they like! Waterproof, solid and strong, all these packaging types provide effective protection for fruit juices and fruit drinks, especially against oxygen (number-one enemy of Vitamin C). All aspects have been designed to make sure each type of packaging offers optimal care of the products and their qualities, preserving their flavour and nutrients. And let's not forget that all types are recyclable, each with its own sorting channel!

9.5.2.2. Packaging materials for processed fruit and vegetables

Various packaging materials are used in the food industry sector of processed fruit and vegetables. We will look in detail at glass, metal options, plastics and cellulosic materials.

Glass receptacles

Glass is a silicon-based mineral material made from silica sand. It is used as packaging for **fruit and vegetables processed into forms such as jam, compote, fruit juice, etc.**, and **offers several important advantages, since it is:**

- Transparent,
- Inert,
- Reusable,
- Recyclable.

Nevertheless, it also has **certain major disadvantages**, including the fact that it is:

- Fragile,
- Hazardous (if broken),
- A poor conductor of heat.

Glass has been used as a food packaging material for several centuries. Glass packaging includes flasks, pots, jars, drinking vessels, etc.

Many food products are packaged in glass:

- Liquids: water, juice, oils, cooling drinks, milk, oils, vinegars...
- Preserves: vegetables, fruit, pâté, meat...
- Jam, honey, sweet spreads...
- Condiments, mustards, seasonings...
- Baby food,
- Milk-based products such as yoghurt...
- Ready-cooked dishes, etc.

The highly widespread use of glass in the food industry has not come about by chance; it is entirely justified by a set of qualities specific to glass, the most important of which are listed above.

- Glass is impervious to gas, vapours and liquids. It is an exceptional barrier material.
- Glass is chemically inert in response to liquids and food products, and poses no compatibility issues; it can be used for all food products in liquid, solid, paste or powder form.
- Glass is hygienic, and inert as regards bacterial action; its surface resists attachment and does not encourage the growth of bacteria or micro-organisms on its surface.
- It is easy to wash and to sterilise.
- Glass has no smell, and neither modifies flavour nor carries traces of it. Using glass ensures the taste and organoleptic properties of the food.
- Glass is transparent, enabling visual inspection of the product.

- It may be coloured, and as such protect against ultra-violet rays that may damage the product inside.
- Glass can withstand the high internal pressures exerted on it by certain liquids.
- Glass has sufficient mechanical strength to cope with impacts sustained in high-output packing chains, and to withstand substantial vertical stacking during storage.
- It is recyclable.
- It allows micro-waves to pass through it so that the product inside can be reheated.

Glass jars containing preserved fruit and vegetables

Metals

- Steel-based materials: tinplate and tin-free steel

  Food cans have a lid that is closed in an airtight seal using a crimping machine. These machines come in different types, from simple hand-operated instruments to new automatic machines. The closure system must be correctly adjusted so as not to risk leakage. Crimping effectiveness is checked by putting a little water in a can, and then sealing it before immersing it in boiling water. If after a few minutes steam can be seen escaping, it means the crimping setup needs adjusting.

  Factory-supplied cans are sufficiently clean; there is no need to wash them. Store them upside down to avoid any contamination. If they are not clean, wash them in hot water containing washing soda (1.5%), then rinse them in hot water and let them drip-dry on a clean tea towel. The lids must also be clean. The main material used in food cans is tinplate: a thin sheet of low-carbon steel, electrolytically coated on both sides with pure tin. A derived product, tin-free steel, now plays a prominent role, accounting for 30% of tonnage across the globe.

- Tinplate

  Tinplate is made of steel, an alloy of iron and other materials, and a tin layer.

  - Steel base material: the chemical composition of the base steel also influences the mechanical characteristics of the packaging, and may contribute to corrosion resistance.
  - Tin plating: Electrolytic tin plating continuously applies a precise quantity of tin to each side of the metal, which has first been stripped and degreased. This deposit is then remelted to obtain an alloy with the steel support and the characteristic shine. After this, the surface receives an electrochemical passivation treatment, in order to end up with a surface layer containing tin oxides, chrome oxides and chrome metal. Lastly, it is very lightly oiled so that it will slide easily and be protected ahead of its final "varnish" coat.

  In practice, the tin coating weights, expressed in g/m^2, are selected depending on the type of can, the contents and the application conditions. Standardisation recommends the following nominal values: 1.0 – 2.0 – 2.8 – 5.6 – 8.4 and 11.2 g/m^2 for each side. However, coating weights lower than 2.8 g/m^2 are not suitable for use on sterilised products.

- Tin-free steel

  This material is composed of steel and a chrome layer. The operation to add the chrome layer is called "chrome plating". Developed in Japan in around 1965, this family of coatings became established in the USA, and then in Europe, as the essential complement to tinplate. The international designation is ECCS (*Electrolytic Chromium Coated Steel*), but its usual name of TFS (*Tin-Free Steel*) is still in frequent use.

- Aluminium

  This material is used a great deal in the food processing industry. It has the following characteristics:

  - Lightweight,
  - Impervious to gases,
  - Recyclable,
  - Flexible,
  - Stable.

  However, aluminium also has certain disadvantages; it is:

  - Relatively expensive,
  - Difficult to close,
  - Limited in its marketing functions (due to limited shape options).

- Protective coatings (varnishes) for metal packaging

  Certain metallic materials, such as aluminium or tin-free steel, are often varnished on their inner and outer faces. The varnishes' essential function is to **minimise interactions between the packaging metals and the packed products**, and between the metals and the outside environment. On the external surface, organic coatings fulfil the dual function of protection and decoration.

  The varnishes are products able to form a continuous, physically and chemically inert, film that adheres to the metal. In other words, any migration that may occur when the container and contents are in contact will not compromise the wholesome nature of the food product.

  The **main constituents of the varnishes** are:

  - film-forming substances (organic polymers);
  - solvents that are necessary for manufacturing and applying the varnishes, but removed during drying;
  - any pigments and miscellaneous additives.

  Non-pigmented varnishes are transparent or colourless; the pigments colour the film and render it opaque. One example is titanium oxide, which is used to produce white coatings. This varnish is starting to become the essential component in inks used in the packaging's external decoration, given the colour and attractive effect it produces.

Multiple possibilities to use metal packaging for fruit and vegetables

Plastics

A significant proportion of packaging in the food processing industry is made of plastic. The practicality of plastic packaging plays a central role for consumers of mass market products. Products that have won consumers' approval have, for example, a pouring spout; this makes it easy and practical to reuse the receptacle, and consequently offers the consumer further service.

Plastic packaging offers infinitely varied solutions; it can be adapted to bespoke needs and endless different products. As it is light and offers value extraction potential, whether by recycling or energy recovery, this kind of packaging meets post-use environmental requirements.

Plastic packaging is strong, and therefore avoids product losses and the risk of damage to the food it protects. It is compatible with the throughput pace of packing in the food processing industry and with the product distribution methods.

All the requirements mentioned above regarding the food product to be packaged – relating to technical aspects, safety, hygiene, compatibility between container and contents, practicality for the consumer, information, marketing – explain the fact that thanks to the diverse material qualities and processing methods they offer, plastics feature in an increasingly vast number of applications.

The different types of plastic used most often are: PET, HDPE, LDPE, PS, PVC, PP.

A: Selecting a plastic material

The rigid primary packaging, *i.e.* the one in contact with the food, must meet a set of constraints. The material must lend itself to the processing technique necessary in order to obtain a bottle, punnet or pot, while also offering the requisite qualities:

- Resistance to impacts, to cold (freezer) and to temperature (e.g. sterilisation, microwave oven);
- Aesthetic appeal on the shop shelf (shape, colour, appearance, transparency, seductiveness);
- Practicality for the consumer: easy to open/close (screw-caps, hinged caps that clip open, peel-off lids), dose dispensers;
- Shelf life: packaging is a barrier to water vapour, oxygen and smells; can be used for modified atmosphere packing;
- Consumer safety: tamper-evident security feature on the opening, sealing.

However, the primary function of food packaging is indisputably to make sure the food product is protected from external contamination, both chemical and microbial, throughout its expected shelf life.

In this regard, all plastic materials offer the properties of imperviousness and harmlessness, often to a satisfactory level even in a **single-layer packaging item, still referred to as a "structural material"**. For food products that are naturally sensitive to the oxygen in air, or to odours, it is necessary to consider **"barrier materials"**. These are now systematically used in **multi-layer packaging**, in association with structural materials.

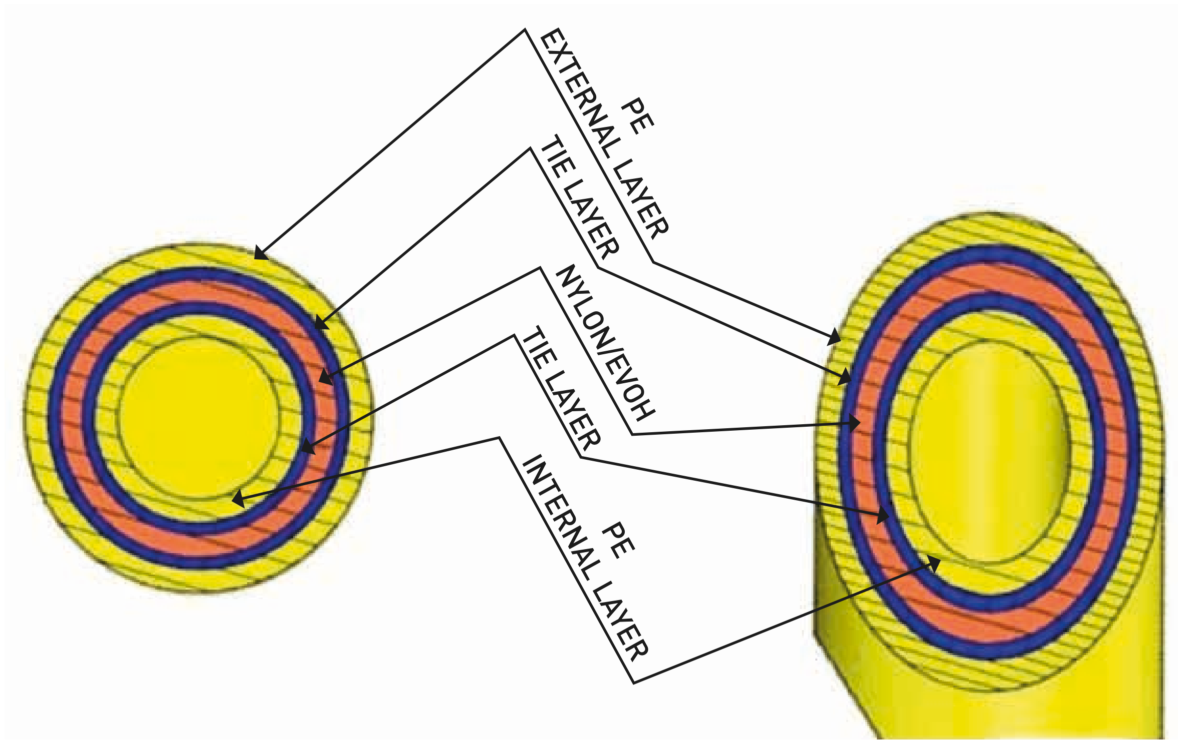
B: "Barrier" materials

These materials have very low permeability to oxygen and carbon dioxide, as well as to heavier molecules such as food aroma particles.

The current trend towards extending products' shelf life is encouraging increasing use of barrier materials. However, their other characteristics, particularly the price, prevent them from being used widely.

- Ethylene vinyl alcohol copolymer (EVOH)

This material is very widely used in **rigid packaging for food**, because it lends itself well to co-extrusion of sheets or hollow shapes **in combination with structural materials**, such as polyethylenes, polypropylene or polystyrene. However, the crystalline and polar nature of EVOH require the use of binders to form an adhesive bond with the structural materials. This copolymer presents **excellent impermeability to oxygen, carbon dioxide and aromas, on condition that it is protected from moisture** which causes a sharp decline in its performance. To overcome this negative point, EVOH is often **sandwiched within multi-layer structures** based on PE (polyethylene) or PP (polypropylene) polyolefins which are not overly sensitive to humidity.



Structure of multi-layer rigid food packaging

Another way of optimising the structure is by adjusting the proportion of ethylene in the EVOH, which varies in practice between 29% and 44% of the weight. Ease of use increases, and sensitivity to moisture decreases, as the ethylene content goes up. On the other hand, the "barrier" properties are reinforced as the proportion of vinyl alcohol increases.

- Polyvinylidene dichloride (PVDC)

This is the family of "barrier" materials most commonly used in soft films. It is comprised of copolymers of vinylidene chloride.

C: "Structural" materials and their association

- Low-density polyethylene (LDPE)

This material is by far the most predominant kind of soft packaging. because it provides an excellent moisture barrier and can be heat-welded within a high-output process. It may be used for liquid food products. Low-density polyethylene is chiefly used in manufacturing shrink-wrap or clingfilm for palletisation.

- High-density polyethylene (HDPE)

This material has the following properties:

- Maximum usage temperature: 105°C;
- Brittleness temperature: -50°C;
- Microwave oven compatible: yes;
- Flexibility: good;
- Very good resistance to acids, aliphatic alcohols, aldehydes, aliphatic and aromatic hydrocarbons;
- Poor resistance to oxidising agents.

It is regenerated and recycled in granule form. HDPE has made remarkable inroads in two sectors where **semi-rigid and opaque bottles** are used: bottles of milk or milk-based drinks, and closure seals for carbonated drinks, etc.

Milk-based fruit drink and milk in semi-rigid, opaque packaging

- Polypropylene (PP)

This material belongs to the family of polyolefins, which are chiefly composed of propene. It features mainly in the manufacture of films used to make packaging for dried fruit and vegetables, to be consumed dry.

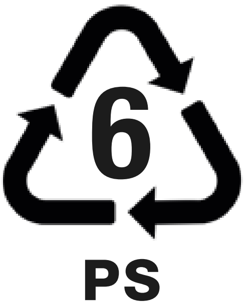
This material offers a number of advantages: good value for money, and suitable rigidity and transparency for food production purposes. It can be seen in use as transparent microwaveable trays of prepared vegetables (but not for cooking the contents from raw), tubs of dried fruit, and disposable cups and plates.

Crystallised ginger and dried mango pieces in polypropylene tubs

In multi-layer applications, PP is also used in the flexible, "squeezable" bottles that contain mayonnaise and ketchup; however, for these packs to be 100% effective they must include an oxygen barrier such as EVOH in a multi-layer structure such as **PP-binder-EVOH-binder-PP**. Thanks to thermoforming, polypropylene has managed to conquer other corners of the market, e.g. packaging for milk-based desserts and fruity fromage frais.

Fruity fromage frais and ketchup, in multi-layer packaging based on PP-binder-EVOH-binder-PP

- Compact polystyrenes (PS)



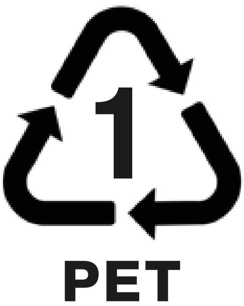
Polystyrene (PS): this polymer of styrene is chiefly used in packaging for dairy products (**yoghurts, crème fraîche, milk-based desserts**) and cups for drinks vending machines. Polystyrene is a material that lends itself "par excellence" **to high-output thermoforming**.

PS still largely dominates as a packing option for fresh dairy products such as yoghurts, milk-based desserts and *fromage blanc*. Moreover, it is the only material used in the Form Fill Seal (FFS) technique, in which thermoforming, product filling and heat sealing of packs are all performed in sequence in one production line.

PS yoghurt pots made using the FFS process are subsequently sold in linear blocks, in sets of 4, 6 or 8 pots still attached together. The consumer can easily separate the pots by folding.

For **products sensitive to oxygen** or to enable a long shelf life, it is necessary to use **multi-layer structures comprising PS/EVOH/PE.** This is the case for fruit compotes.

- Polyethylene terephthalate (PET)



This plastic in the polyester family, unlike PVC, has very low permeability to CO_2. It is therefore used in manufacturing bottles for carbonated drinks. Polyethylene terephthalate (PET) has become the go-to material for packing **salad oils**, because it offers better protection (than PVC) against oxygen ingress, and high resistance to impacts. Photo-oxidation that alters food products in transparent packaging can be minimised by using UV stabilisers or colourless ingredients that absorb UV radiation.

The use of PET, like polypropylene, for packaging applications is in a strong growth phase, especially in bottle-type packs to contain **drinks and bottled water.**

- PVC

This represents a very small proportion of plastic packaging. It is used in making narrow and wide-neck bottles (for still or slightly sparkling mineral water, with or without fruit flavours, and for fruit vinegars and oils).

Cellulosic materials

Wood is used to pack dry and fresh fruit (apples, mangoes, dates, raisins, etc.); it offers ease of handling and stacking. Wood is also used in making glass bottle stoppers, produced using cork (from the "cork oak" tree). Cardboard and paper are used as packaging for fruit and vegetables. These types of packaging offer a way to combine the advantages offered by the different materials.

Combinations of materials

Due to the advantages and disadvantages of each packaging type, we will try and bring together the complementary properties of each material in order to devise an effective packaging solution. For example, opting for cardboard would mean using a renewable resource, but the lack of impermeability is a problem. We will therefore combine cardboard with plastic, which offers advantageous properties in terms of keeping water out. The developers of TetraPak were among the first to create composite packaging, by combining cardboard, plastic and other materials to create their well-known drinks cartons.

9.6. PALLETISATION OF PACKAGES

A large number of loaders have transitioned from handling individually shipped packages to single-unit loads on a pallet.

Most distribution centres are designed to store palletised loads in racking on three levels. Single-unit loads are advantageous because they:

- Reduce individual handling of packages being shipped;
- Reduce the risks of damaging packaging and the products within it;
- Speed up loading and unloading of the transport equipment;
- Enable distribution centres to operate more efficiently.

Single-unit loads may, for example, have some of the following characteristics:

- Standardised wood pallets or panels measuring: 1200 x 1000 mm, 800 x 1000 mm, 800 x 1200 mm or 1000 x 1200 mm;
- Vertical separators between cardboard/plastic crates or metal cages;
- Crates with holes allowing air circulation; the holes line up when the crates are stacked on top of one another, with their corners meeting;
- Application of glue between boxes to prevent them sliding horizontally;
- Film or plastic net wrapping around the palletised load of boxes; edge protectors made of stiff cardboard, plastic or metal; plastic or metal strapping around the corners and the boxes.

Wood pallets must be sufficiently strong that they can be stored in racking on three levels. Handling with forklift trucks and pallet jacks must be possible. The base of the pallet must be designed to allow air circulation.

Pallets must have enough deckboards comprising their upper surface to support the boxes; otherwise the boxes may, under the weight of other packages above them, cave and sink between the boards of the pallet surface, crush the product and cause the whole load either to lean or to fall off the pallet. A sheet of perforated cardboard, allowing air circulation, can be used to distribute air throughout the pallet surface.

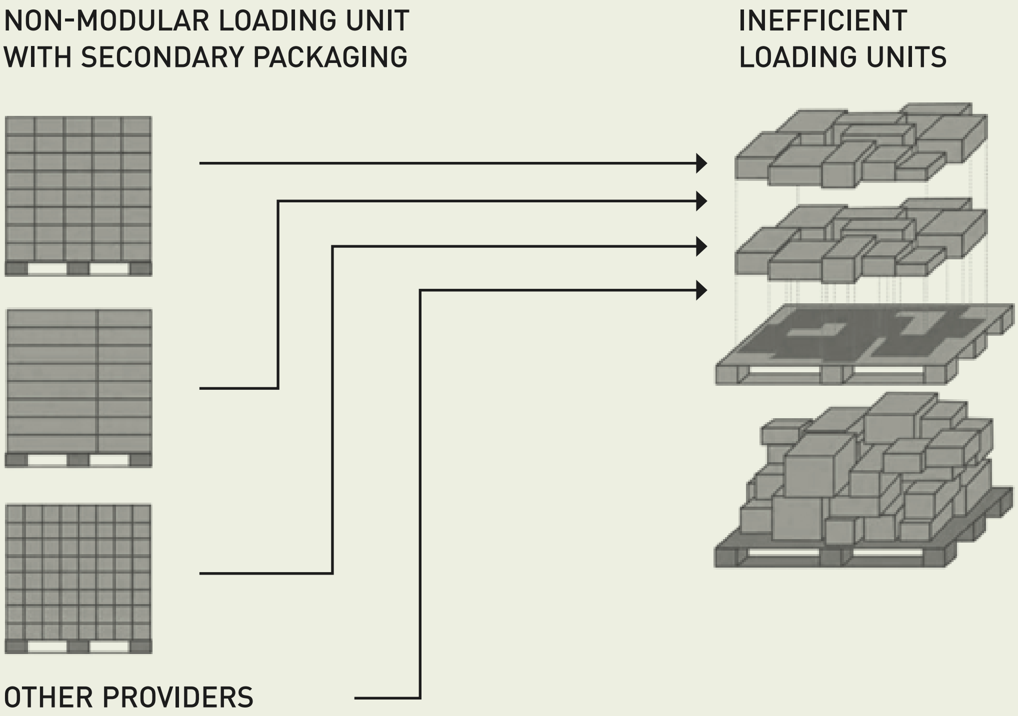
Boxes must not extend beyond the pallet edges. An overhang can reduce the strength of cardboard boxes by a third. It can complicate the tasks of loading and unloading, and of storing the load on racks; it can also lead to the entire load collapsing and crushing the product. On the other hand, if boxes take up less than 90% of the pallet surface and are not lined up with the edges, they can slide around or shift during transport.

If palletised loads of packages for shipment are not banded or wrapped in nets, the top three (at least) layers of their packages must be stacked in both directions (*i.e.* in an overlapping brick-type pattern) to ensure stability. Certain loaders use plastic film, adhesive tape or glue on the upper layers, applied in both directions in addition to the stacking. The packages must be strong enough to be stacked in both directions (overlapping pattern) without caving in. Products that are placed in shipment packages but need air circulation must not be wrapped in plastic film.

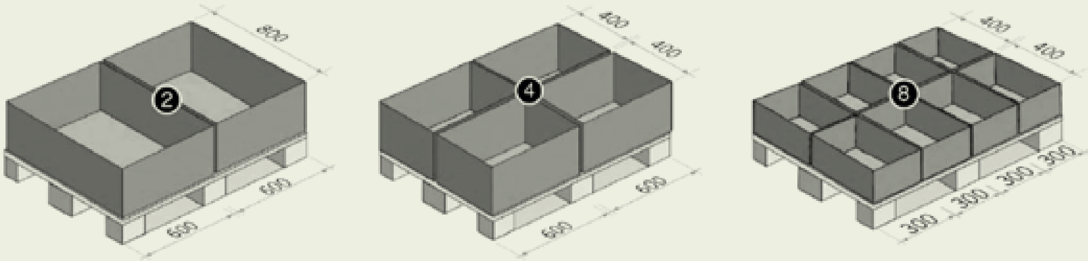
Some loaders use panels, as these are less expensive than pallets. Furthermore, they eliminate the costs of transporting pallets and having them returned. If loads are placed on panels, a special forklift truck is necessary to move them off pallets and onto pallets, in the loader's and receiver's distribution centre. If a receiver does not have the appropriate handling equipment, the packages are unloaded manually onto the pallets in order to be stored. Shipment packages on panels are stacked in both directions, wrapped in plastic sheeting or otherwise grouped together into loading units using edge protectors and strapping.

Panels made of cardboard or plastic must be strong enough to withstand being grasped and placed on the truck's loading forks or on a board, to be lifted while fully loaded. Cardboard panels must be waterproofed if they are to be used in wet conditions. Panels used as part of transport equipment must be perforated so that air can circulate under the load. The use of panels for loads comprising refrigerated transportation equipment, with shallow grooves at floor level, is not recommended because it does not allow sufficient air circulation.

NON-MODULAR PACKAGING SIZES



MODULAR PACKAGING SIZES



Examples of efficient and inefficient loading units

9.7. PRODUCT MARKING

9.7.1. Labelling of fresh fruit and vegetables

Labelling is a prerequisite for traceability. However, "labelling" does not mean "tracing". Putting a mark on a product **facilitates its identification and contributes to the reliability** and systematisation of traceability, be it *tracing* or *tracking*.

On the other hand, while traceability involves several companies along the industrial and logistics chain, the mark will only be useful if it can be used by the other companies concerned: this is why it is necessary to use "marks" or "codes" that are legible and usable

by all operators in a chain (see below).

Labelling must:

- Be done with a system other companies can use;
- Refer to code that is comprehensible by these companies (standards). Reading and not understanding a label is of little use;
- Be suited to the purpose and visible: an inaccessible or hidden label is useless.

Labelling products implies pre-definition of the relevant labelling level. Labelling at the unit level can be useless (and, therefore, be a needless cost) if **labelling lots** or **logistics units** is sufficient.

The answer will depend on the use made of the product downstream and on the identification needs that arise during its life cycle.

9.7.2. Data carried by products

The information carried by an entity is **isolated** traceability data which are, therefore, incomplete and of little interest in themselves.

Traceability data can be categorised as:

- **Legally required information** (BB or best before date, etc.);
- **Legal information** on packaging;
- **Labelling formats** (e.g. EAN-128, a widely used product identifier[57]).

The following are used when **tracing at the unit level**:

- A product identifier;
- A unit serial number.

57 EAN combines a standardised code and symbology.

The following are present when tracing at the group level (**product lot**):

- A product identifier;
- A lot number (logistics lot or production lot) that can be expressed in several different ways:
  - Incremental sequential number (including the SSCC or Serial Shipping Container Code[58] for the logistics unit);
  - Time chart information (date and time).

Identification information must always be **in plain text** and **visible**.

Every lot of food products sold must be unequivocally identifiable. In the event of an emergency, or if a withdrawal or recall must be organised, the identification must enable suppliers, customers and the competent authorities to find the lot(s) in question and their origin without error.

In compliance with the ***Codex Alimentarius* standard**[59], each package must, as a minimum, have the following information printed on the same side, in legible, indelible characters visible from the outside:

Identification

- Exporter, packager and/or shipper (and national registration number),
- Lot number.

Type of product

- Product name, if the contents are not visible from the outside,
- Name of the variety or commercial type (if required).

Product origin

- Country of origin and, optionally, the region of production or national,
- regional or local appellation.

Commercial characteristics

- Category,
- Calibre (reference letter or weight scale),
- Number of units (optional),
- Net weight (optional).

Official inspection stamp (optional)

58 A number unequivocally identifying the goods on which it is placed, from exporter to end customer. Thanks to the SSCC, the product's movement can be followed through the supply chain, and links created to corresponding information (e.g. data previously recorded in producer logs).

59 CAC/GL 60-2006, *Principles for traceability/product tracing as a tool within a food inspection and certification system.*

This information can also be included in the product shipping documents.

In addition, certain lots of plants or plant products intended for the European market and potentially carrying pests must include a Phytosanitary certificate.

9.7.3. Marketing standards

Many fruits and vegetables are subject to marketing standards. Additional marking standards may also apply, in connection with professional agreements. These requirements are specified on a case-by-case basis (see table).

Table: Illustration of the standards applicable to fruit and vegetables

Fruit and vegetables (F&V) and Common Organisations of agricultural Markets (CMO)		Marketed varieties of fruit or vegetable	Marketing standard (mandatory/optional)
CMO for "Farm products"	CMO for "Fruit and vegetables"	Lemons and limes / clementines, mandarins and hybrids / strawberries / kiwi fruit / oranges / peaches and nectarines / apples / pears / sweet peppers / table grapes / salad leaves (lettuces, curled-leaved and broad-leaved endives) and tomatoes	Specific standard for the product
		Most other fruits and vegetables	General marketing standard or UN-ECE standard (if there is one) or *Codex* standard (if there is one)
	CMO for "Other products"	Chilli peppers, coconuts, ginger, peanuts...	No standard.
	CMO for "Green bananas"	Green, unripe bananas (Cavendish and Gros Michel)	Standard for green bananas

9.7.4. Legal information in fruit and vegetable marking

9.7.4.1. Identification

The packer's or shipper's name and address are mandatory on packaging at the shipment and wholesale stages (e.g. street / town / region / postcode and country, if different from the product's country of origin). The named country of origin is the one in which the fruit or vegetable was grown and harvested.

However, this indication can be replaced in certain situations:

- For pre-packed fruit and vegetables: replace country of origin by the officially issued or accepted code mark representing the packer and/or the shipper, indicated in close connection with the reference "packer and/or shipper" (or an equivalent abbreviation); the ID code is preceded by the ISO 3166 (alpha) code of the recognising country / region, if this is not the country of origin;
- For pre-packages only: by the name and the address of a seller established within the European Union indicated in close connection with the mention "Packed for" or an equivalent mention. In this case, the labelling shall also include a code representing the packer and/or the shipper. The seller shall give all information deemed necessary by the inspection body as to the meaning of this code.

The **full name of the country of origin** must appear on:

- The packaging (parcels, pre-packaged, etc.),
- The showcards at the point of sale,
- Leaflets and advertising posters,
- Merchant sites (online).

Any further information on the region or area where the product is made may be added.

9.7.4.2. Type of product

Several pieces of information refer to the "nature" of the product; in particular the **common name of the produce item** (e.g. mango, peach, nectarine, banana...). At the initial marketing stage (shipment/wholesale), this indication is required by regulations "where the contents are not visible from the outside".

Some standards require indications in addition to the produce name. For example, the following:

Name of variety: imposed by certain specific standards (e.g. for apples, pears, etc.) or UN-ECE standards. It is optional for other products (peach, kiwi fruit, strawberry, tomato, etc.). Taking mangoes as an example, if the product is visible from the outside, it would be acceptable to indicate only the variety name (e.g. "Kent"), without specifying "mangoes". However, the application indicates: "mango" and "name of variety". In the case of a mixed package containing mangoes of different varieties, the names of the varieties must be specified. The name of the variety can be replaced with a synonym. A marketing name (a brand name for which trademark protection has been sought or obtained, or any other commercial name) can only be given in addition to the name of variety or a synonym. In the case of mutants with varietal protection, the name of their specific variety may replace the basic name of the variety. In the case of mutants without varietal protection, their name can only be given in addition to the basic name of the variety.

Name of the commercial type: required by certain specific standards or UN-ECE standards, or sometimes only "where the contents are not visible from the outside" (e.g. the standard for tomatoes distinguishes between several commercial types: "round", "oblong", "ribbed", etc.).

Other indications are imposed by certain specific standards or UN-ECE standards, for example:

- The colour of the flesh, for peaches or nectarines,
- The specification "cut" or "uncut" for cultivated mushrooms,
- The indication "grown under protection", for salads to which this applies.

9.7.4.3. Marking relating to the quality category

Even though certain indications such as the type of product, the country of origin and the price by weight/per unit are mandatory for retail sale of fruit and vegetables, the mention of a category (Extra, or I, or II) is only compulsory for certain products subject to a specific standard, such as potatoes.

For the majority of fruit and vegetables not subject to the specific standard, the regulations **do not require the quality category to be stated**. They are subject to the "general" marketing standard. In this case, European regulations leave it up to the operator to choose whether to apply the general marketing standard or the UN-ECE standard for the product in question, if there is one. In the absence of an UN-ECE standard, a *Codex* standard can also be applied if there is one for the product.

9.7.4.4. Marking of fruit and vegetable calibres

Specifications on calibre marking are provided in the text of the various marketing standards. The "general marketing standard" makes no stipulations on calibre.

The marketing standards for individual products specify the provisions on calibres:

- Determining the calibre, *i.e.* how one measures the calibre of the product,
- The minimum calibre (if applicable),
- The "calibre codes" used (if there are any),
- The calibre brackets that impose uniformity on a given package, etc.

At the shipment and wholesale stages, on the packaging labels, the indicated calibre may sometimes be preceded by the terms "calibre" or "cal". Indicating the unit of measurement used to express the calibre (mm, cm, g, etc.) is highly recommended, as this facilitates exchanges between professionals, and aids calibre checking at the approval stage.

9.7.4.5. Post-harvest treatment

Marketing standards require labelling to indicate treatment applied after harvesting (post-harvest). This is the case for the specific standard on citrus fruit (applicable to oranges, lemons/limes, clementines, mandarins and hybrids).

If such treatment has been applied, a mention of the preserving agent(s) or other chemical substance(s) used at post-harvest stage must appear on the packaging labels (packages, nets, etc.). Certain waxes, authorised for use on citrus fruit and constituting post-harvest treatment, must be mentioned:

- Printed in full: carnauba wax, Shellac, etc.
- And/or with the relevant E number: E 903 and E 904 respectively.

The European Commission has made it obligatory at the retail stage to mention the use of preserving agents in post-harvest treatment (information from early 2020).

9.7.4.6. Marking the net weight of pre-packed products

It is mandatory to indicate the net weight of fruit and vegetables presented pre-packaged. The net weight is expressed in grammes (g) or kilogrammes (kg). The net weight can be replaced by the number of items in the pack (except for small fruits / vegetables or when the number of items is large, *i.e.* more than 6 – for example, a bag of 4 lemons).

9.7.4.7. Marking the lot number of fruit and vegetables

It is mandatory to indicate the lot number on the label of fruit and vegetables presented pre-packaged. A date may be used instead (e.g. date the product was packed). For non-pre-packaged products (e.g. pack of loose or laid out items) the lot number is shown on the pack, or – failing this – on the marketing documents.

9.7.4.8. Other indications relating to fruit and vegetable marking

Nutritional claims

Quantitative claims about nutrition content are as follows: low in, source of vitamins/ minerals, rich in vitamins/minerals, naturally contains vitamins, naturally rich in vitamins, sugar-free, no added sugar, source of fibre, source of protein, guaranteed magnesium content, and so on.

The obligation to declare nutrition content (calorific value, quantity of carbohydrates, sugars, etc.) **does not apply to unprocessed fruit and vegetables.** Therefore, a nutrition statement is not necessary for fresh, whole fruits and vegetables (referred to as "first range") and dry products (garlic, onions, shallots, walnuts, hazelnuts etc.) whose surfaces have dried slightly.

On the other hand dried products (e.g. apricots, dates, prunes, raisins...) **have been modified throughout, and are consequently required to have a nutrition statement.**

Fruit and vegetables that have received basic preparation (1st range) and those that have been made ready for use (4th range) are also not required to have a nutrition statement.

If any seasoning, sugar, etc. is added, the nutrition content must be declared. Fresh fruit juices are considered to be processed products, and therefore require a nutrition statement, unless they are prepared for immediate sale. In this final case, it is not necessary to declare the nutrition content.

Health claims

Claims are statements that assert or suggest that a food item possesses particular characteristics associated with criteria. Claims generally pertain to the origin, nature, composition and nutritional properties of a product (e.g. natural, fresh, new, pure, home-made, artisan-made, old-fashioned, traditional, free-range, no artificial colourings, no additives).

A health claim is a message that asserts, suggests or implies a relationship between a food item (or one of its ingredients) and health. Regulations distinguish between three types of health claim:

- Claims about alleviating an illness,
- Claims about the development and health of children,
- Other claims mainly relating to vitamins and minerals.

9.7.5. Traceability codes

Packaging must also enable **identification**: one of its jobs is to collect information about the product, at precise moments in its journey through the production, packing and marketing process. It **combines five elements**: an object (the item), a place, a time, a context and an operation.

Traceability, which is necessary and mandatory in the food production chain, encourages the use of standards or "codes", because it overflows from companies both upstream and downstream. Inventing rules is a waste of time: at some point or another, it will be necessary to provide consistency with a standard. A typical example is the **EAN (GS1) code**, which is used to identify everyday consumer products. This code is placed by the manufacturer and is readable by all the shops in which the product is sold.

The use of standards offers **four advantages**.

1. Standards are the common language of an industry: **using them strengthens sector integratio**n, and over time provides the means to enter into a relationship with other sector partners.
2. Standards are created through consultation and are related to good practices. Using them results in greater expertise.
3. Standards are designed to cover all possibilities. Using standards increases reliability.
4. Most solutions and tools available conform to standards. Using them leads to time and resource savings.

Standards exist in all sectors and can be of several types.

For example:

- GS1/EAN UCC **for mass market products**[60];
- GLN (Global Location Number) identifies **destinations**;
- SSCC (Serial Shipping Container Code) **identifies packages**;
- GTIN (Global Trade Item Number) **identifies products** (units sold to consumers);
- CIP 13 identifies medicines;
- Galia identifies automobiles;
- Etc.

9.7.5.1. The GLN (Global Location Number), international location-function code

This is a unique international 13-digit code used to designate a location. It can be:

- **a company:** company, subsidiary, etc.
- **a functional entity:** accounting department, warehouse, etc.
- **a physical entity:** room, hospital room, storage aisle, etc.

"301" or "302"	National supplier or retailer code	Internal code	Control key
3 digits	5 to 8 digits	1 to 4 digits	1 digit

9.7.5.2. The GTIN (Global Trade Item Number)

This is a unique international 13-digit code used to designate product units that can be purchased by consumers. It is an extension of the EAN-13 code.

Generally speaking, a unique international number is assigned to each commercial unit (for example, a plastic-wrapped tray containing a bunch of tomatoes intended for a point of sale) or a standard group of commercial units (for example, a pallet containing several vats of tomatoes, transferred from the warehouse to a retail shop). This is the **GTIN** (Global Trade Item Number). The GTIN contains no information on the product. It is simply a unique key providing access to information stored in databases. Four GTIN numbering systems are available for the identification of commercial units: GTIN-14, GTIN-13, GTIN-12 and GTIN-8. Selection of a numbering system depends on the type of product and the application.

---

60 Prior to this standard, European manufacturers and retailers used EAN (European Article Numbering) standards and North Americans used UCC (Uniform Code Council) standards.
The GCI (Global Commerce Initiative) is a working body created in 1999 by industrialists, retailers (Auchan, Carrefour, Tesco, etc.) and manufacturers (Nestlé, Coca-Cola, Procter & Gamble, Johnson & Johnson, etc.) to facilitate integration of the supply chain and to simplify business processes.
It works toward the convergence of current coding standards. For example, GCI projects include support for GLN (Global Location Numbers) and GTIN (Global Trade Item Numbers). It launched the GSMP (Global Standard Maintenance Process) in January 2002. EAN (European Article Numbering) and UCC (Uniform Code Council) also joined forces, and new standards are being designed for the global system of **EAN-UCC standards**.

SAMPLE USE OF GTIN-13

5 412345 000013

5412345: GS1 company prefix (in this example, assigned by GS1 Belgium & Luxembourg)

00001: item number assigned by the company

3: control key

There are now **GTIN+** codes (*i.e.* the GTIN code + the lot number or the expiration date (BBD, Best Before Date) or the production date (PD, Production Date)) and an **SGTIN** code (GTIN with the serial number of the item).

9.7.5.3. The SSCC (Serial Shipping Container Code)

The SSCC is an 18-digit GS1 number that unequivocally identifies the logistics unit on which it is placed. It is used in logistics **to number packages** (e.g. pallets). For example, three identical items sent in three different packages will have the same EAN-13 item number but different SSCC codes. Every SSCC number is different around the world.

Open	Country	Manufacturer code	Sequential number	Control key
1 digit	1 digit	5 to 8 digits	7 to 10 digits	1 digit

In combination with the EDI despatch advice, the SSCC ensures quick and correct reception of merchandise. In addition, all the data tied to the logistics unit, namely the approval number, the GTIN(s), the packaging date, etc. can be exchanged via EDI using the SSCC as a reference. The SSCC is therefore a pure traceability tool.

THE SSCC IS MARKED ON THE LOGISTICS UNIT USING UCC/EAN-128 SYMBOLS

(00)154123456000012345

00: Application Identifier (AI) introducing the SSCC

1: serial number extension (between 0 and 9)

54123456: company prefix (if using an 8-digit prefix)

00001234: serial number

5: control digit

9.7.5.4. Barcodes

Barcodes carry information. Their purpose is to code relevant data about a product or service at every step of the supply chain.

Logical identification (location, products, packages) is most often printed and read using a barcode. The use of barcodes is always subject to physical characteristics (size and shape of the media, background colour, etc.).

Depending on these characteristics and the number of digits

used, several standards co-exist:

- **EAN-8** and **EAN-13**: 8 or 13 digits (written in plain text under the bars) – used
- essentially for consumer products;
- **ITF 14:** 14 digits: these data are larger and more clearly legible. They are primarily used in logistics on packing (boxes, pallets, etc.);
- **UCC / EAN-128:** a new standard enabling representation of a variable-length chain of alphanumeric characters.

When additional information about a product is needed in the fruit and vegetables chain – for example the lot number, the weight or the packaging date – **UCC/ EAN-128** symbols can be used to encode the extra data in addition to the product identification (GTIN). This may be the date the product was palletised, the operator's national authorisation number and the net weight.

GS1 Application Identifiers (AI) must be included in UCC/EAN-128 barcodes. They define the structure of the data coded in the data elements they introduce.

(01) 05425004000044 (13)021007 (7030) 0564607710013

Application Identifier (AI) (01) is the GTIN

Application Identifier (AI) (13) is the packaging date, in this case 7^{th} October 2002

Application Identifier (AI) (7030) is the producer's national authorisation number

9.7.5.5. The QR (Quick Response) Code

The **QR code** is a two-dimensional barcode (or **matrix code**) consisting of black modules arranged on a square white

background.

The name QR is the acronym for "Quick Response", because its data content can be decoded quickly. Intended for use with a QR code reader, a mobile telephone, or a smartphone, it offers the advantage of being able to store more information than a regular bar code.

QRs can store up to 7,089 numeric characters or 4,296 alphanumeric characters which is far above the capacity of barcodes.

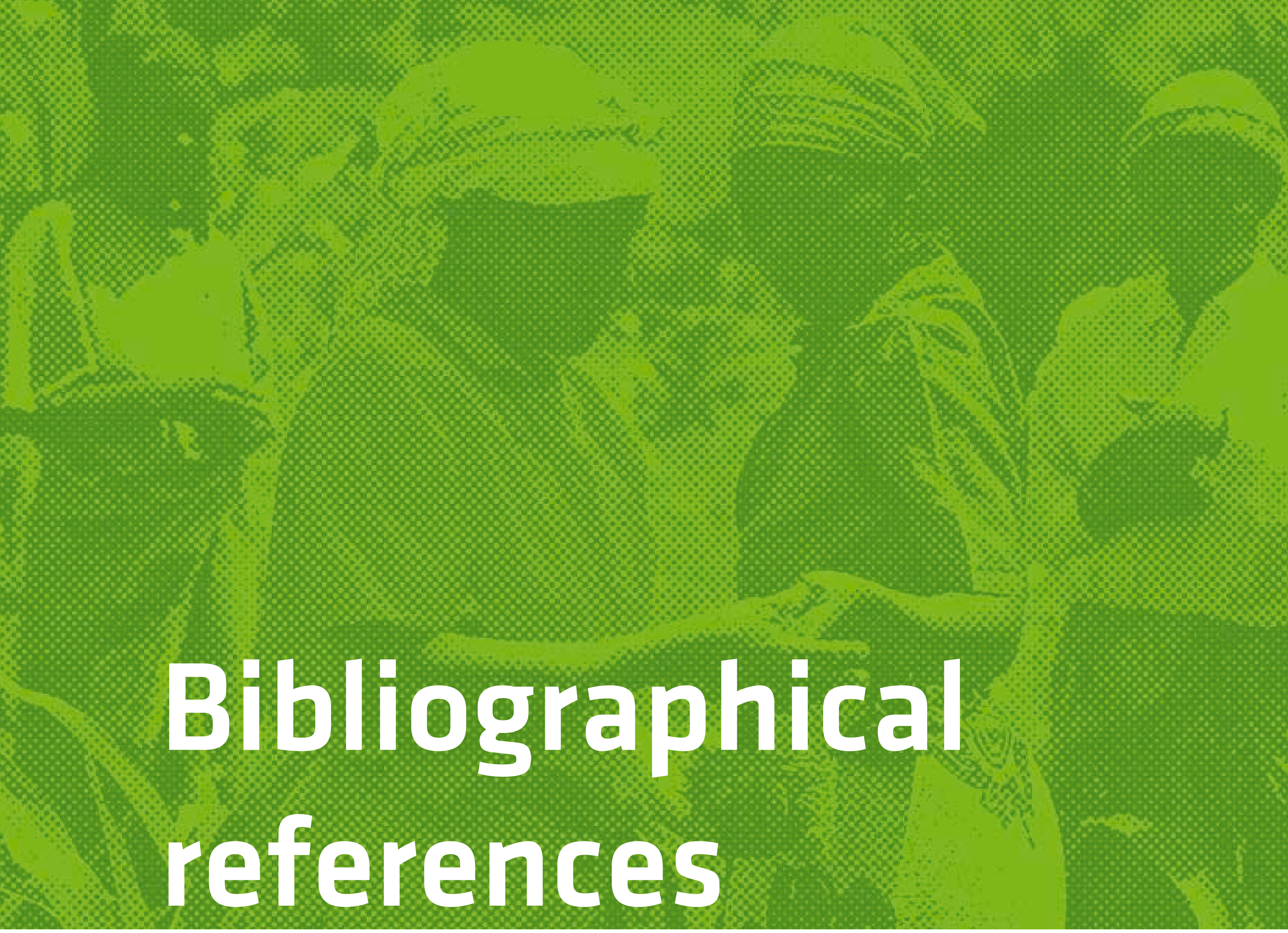
They are found on many different media: they simply have to be scanned using the photo mode of a mobile telephone and sent, in order to receive information directly (composition, origin, lot number, manufacturing date, etc.). Despite its cost, QR code applications are being rolled out for certain food products (e.g. olive oils in Italy).

Most used abbreviations and acronyms

MOST USEFULL ABBREVIATIONS AND ACRONYMS

ACP	Africa – Caribbean – Pacific (ACP countries that have signed a series of special agreements with the EU called the "Cotonou Agreement")
LCA	Life Cycle Analysis
GAP	Good Agricultural Practice (a set of conditions of application that should be defined: dose, volume, formulation, technique, PHI)
GLP	Good Laboratory Practices
GPPP	Good Plant Protection Practice (a set of instructions to be followed to avoid residues and contamination of the operator and environment)
GHP	Good Hygiene Practices
CCP	Critical control points (in the HACCP method)
IPPC	International Plant Protection Convention
PHU	Pre-harvest Interval (number of days to be observed before harvest)
ADD	Acceptable Daily Dose (in mg/kg of body weight/day).
FAO	Food and Agriculture Organisation: United Nations organisation responsible for dealing with food problems across the World
FLO	Fairtrade Labelling Organisations International (FLO) is a group of 20 Fairtrade labelling initiatives in over 21 countries
HACCP	A system that defines, evaluates and monitors the threats against food hygiene (hazard analysis and critical control points)
IPM	Integrated Pest Management
JECFA	Joint FAO/WHO Expert Committee on Food Additives
MRL	Maximum Residue Level
ML	Maximum Limit applicable to certain chemical contaminants

LoQ	Limit of quantification (also LoD: limit of Detection)
PVS	Private Voluntary Standards
OECD	Organisation for Economic Cooperation and Development
IIOC	Independent International Organisation for Certification
EPPO	European and Mediterranean Plant Protection Organisation
GMO	Genetically Modified Organism
IOBC	International organisation for Biological Control
WTO	World Trade Organisation
WHO	World Health Organisation
NGO	Non-Governmental Organisation
UN	The United Nations
QMS or QMSH	Quality Management System or Quality Management System for Healthcare
FDO	Foodborne Disease Outbreaks
EU	European Union



Bibliographical references

BIBLIOGRAPHICAL REFERENCES

There are many relevant resources for processing, packaging, labelling and packing in general. Similarly, there is an abundance of scientific literature on hygiene, micro-organisms, preservation techniques, etc. In preparing this text, many sources have been researched, however editors have largely taken their information from the following works, if the reader wishes to read further into any subject:

AFOC
Guide de conservation des fruits et légumes.
("A Guide to Preserving Fruits and Vegetables.") 6 pages.

AFD (2009)
Normes de qualité pour les produits agroalimentaires en Afrique de l'Ouest.
("Quality standards for agri-food products in West Africa.") Study carried out by Arlène Alpha, Cécile Broutin, Gret, in collaboration with Joseph Hounhouigan and Victor Anihouvi, Faculty of Agronomic Sciences in Benin. 217 pages.

Croix-Bleue ("Blue Cross") (1995)
Guide pour la préparation des fruits tropicaux.
("Guide to the preparation of tropical fruits). 71 pages.

COLEACP (2017)
Principes d'hygiène et de management de la qualité sanitaire.
("Principles of hygiene and sanitary quality management.") Brussels, Belgium.

COLEACP (2011)
Traceability. Brussels, Belgium.

CTA (2003)
La conservation des fruits et légumes. ("Preservation of Fruits and Vegetables.") Agrodok Series no. 3 Agromisa Foundation and CTA edition. 94 pages.

CTA (2008)
Conservation des légumes feuilles et des fruits
("Preservation of Leafy Vegetables and Fruits.")
Collection Guides pratiques du CTA, N°8.
("CTA Practical Guide Series, No. 8.") 6 pages.

CTA (2011)
Le conditionnement des produits agricoles.
("Preservation of Agricultural Products.")
Agrodok Series No. 50. Agromisa Foundation and CTA edition. 78 pages.

CTA -ILO- WEP (1990)
Small_Scale Preservation of Fruits 244 pages.

Marie-Bernard Diligent (2010)
Les confitures : de l'art aux techniques.
("Jams: from the art to the techniques.")
Mémoires de l'Académie Nationale de Metz.
("Memoirs of the National Academy of Metz.") pp. 171-190.

EUFIC (2020)
Des conservateurs pour prolonger la durée de vie des aliments et améliorer la sécurité. ("Preservatives that extend the shelf life of food and improve safety.")
Web page.

FAO (1992)
Prévention des pertes après récolte : fruits, légumes, racines et tubercules.
("Prevention of post-harvest losses: fruits, vegetables, root vegetables and tubers.") Training manual Food and Agriculture Organisation of the United Nations. Rome, 132 pages.

FAO (2004)
Technologies combinées de conservation des fruits et des légumes.
("Combined preservation technologies for fruits and vegetables.")
Training manual Food and Agriculture Organisation of the United Nations.
Rome, 75 pages.

INRS (2003)
Hygiène et sécurité dans le domaine de la distribution alimentaire.
("Hygiene and safety in the field of food distribution.") TJ22.
Legal memorandum. 25 pages.

PAFASP-COLEACP (EDES) (2013)
Bonnes Pratiques pour le séchage des mangues au Burkina Faso.
("Good practices for drying mangoes in Burkina Faso.")

PREUD'HOMME R. (2020)
Agri-food Industries Technology Course. Technology of Vegetables.
Haute École of the Province of Liège, La Reid. 42 pages.

Michel Rivier et al. (2009)
Drying mangoes. Practical guide. Quæ editions, CTA.

UNIDO (2005)
A Guide to Drying Figs US/MOR/04/A48. 27 pages.

Thank you to the authors of these publications!

Useful Websites

USEFUL WEBSITES

FAO
http://www.fao.org/home/en/

WTO
https://www.wto.org

Codex Alimentarius Commission
www.codexalimentarius.org

List of *Codex* food standards
http://www.fao.org/fao-who-codexalimentarius/codex-texts/list-standards/en/

For additional information on SPS measures, visit the WTO SPS portal
https://www.wto.org/english/tratop_e/sps_e/sps_e.htm

For additional information on TBTs, visit the WTO TBT portal
https://www.wto.org/english/tratop_e/tbt_e/tbt_e.htm

To view the WTO SPS measures text
https://www.wto.org/english/docs_e/legal_e/15sps_01_e.htm

To view the WTO TBT text
https://www.wto.org/english/docs_e/legal_e/17-tbt_e.htm

For more information on the Workshop on risk analysis organised by the SPS Committee in 2014
https://www.wto.org/english/tratop_e/sps_e/wkshop_oct14_e/wkshop_oct14_e.htm

To research TBT notifications and for information on specific trade concerns, as well as other TBT matters, consult the TBT information management system
http://tbtims.wto.org/en/

To research SPS notifications and for information on specific trade concerns, as well as other SPS matters, consult the SPS information management system
http://spsims.wto.org/en/

To receive e-alerts regarding SPS and TBT notifications, refer to ePing
https://www.epingalert.org/en

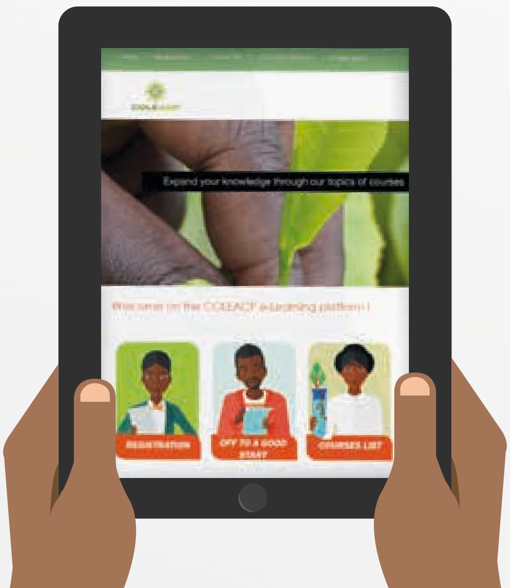
COLEACP E-LEARNING PLATFORM

RECEIVE YOUR ACCESS TO OUR DISTANCE LEARNING PLATFORM.
RESERVED FOR STAKEHOLDERS IN THE AGRICULTURAL SECTOR IN AFRICAN, CARIBBEAN AND PACIFIC COUNTRIES.

TEST AND IMPROVE YOUR KNOWLEDGE AT YOUR OWN RHYTHM!

TOPICS

- FOOD SAFETY
- ENVIRONMENTAL MANAGEMENT
- PLANT HEALTH
- MANAGEMENT OF ORGANISATIONS AND BUSINESS DEVELOPMENT
- SOCIAL ACCOUNTABILITY AND EMPOWERMENT
- SUSTAINABLE PRODUCTION AND TRADE
- AGRICULTURAL PRODUCTION AND PROCESSING



https://training.coleacp.org

SUSTAINABLE PRODUCTION AND TRADE

PLANT HEALTH

FOOD SAFETY

AGRICULTURAL PRODUCTION AND PROCESSING

SOCIAL ACCOUNTABILITY AND EMPOWERMENT

ENVIRONMENTAL MANAGEMENT

MANAGEMENT OF ORGANISATIONS AND BUSINESS DEVELOPMENT

TRAINING METHODOLOGIES

COLEACP