Zero WASTE

AWARENESS FOR THE REDUCTION OF FOOD WASTE

KNOWLEDGE MODULE A:

Food chain, food quality and food spoilage

Co-funded by the Erasmus+ Programme of the European Union

General information. Knowledge Module A

Title:
Food chain, food quality and food spoilage

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Duration:
6 hours – The duration of this module is four hours of the lesson and two hours the practice of the exercises.

Objective:
To deepen the basics of food chain and food quality, and the food spoilage and contamination causes as well as the strategies for their prevention..

Introduction:
This module introduces the concept of food chain and food quality, and defines what is shelf-life of foods. Then, it focuses on food labelling and the information for consumers that helps to ensure that food will be stored and used properly, preventing food waste. It deeply explains the meaning of date of minimum durability ('Best before') and the 'Use by' date. Nutritional components of food are detailed, as well as the information that makes it easier for consumers to choose healthy diets. Waste of valuable nutrients through food loss and waste is also explained. The module goes deeply on food spoilage and contamination, and on food storage and different preservation strategies to minimize their impact. Finally, food safety in the redistribution of food is described.

Learning outcomes
On successful completion of Module A participants should be able to…

Knowledge
- Understand the concept of food chain.
- Know what is food quality, and shelf-life of foods.
- Understand the information shown in food labels.
- Know the factors and mechanisms of food spoilage and the concept of food contamination.
- Know proper food storage and preservation strategies to delay food spoilage.
- Know the importance of food safety in the redistribution of foods.

Technical skills
- Knowing how to interpretate food labelling, particularly being able to distinguish between 'Best fefore' and 'Use by' dates.
- Improving food preservation at home.

Soft skills

- Appreciate the benefits of preventing food spoilage and contamination as a way to minimize food waste

Main contents

1.| Food chain and Food quality. Shelf-life of foods

1.1 | Food chain and food quality

As it has been explained before, food undergoes a series of operations until it reaches the consumer that altogether are called Food Chain. These set of phases or stages necessary for obtaining food from primary production to consumption influence the types of food available and accessible, as well as the way they are produced and consumed (HLPE, 2017). Strategies that consider the entire food system as a whole, from producers to consumers, are known with the term “From farm to fork” and must be applied in order to make the food chain sustainable and safe (Figure 1).

In general it can be said that food chains have become increasingly length and complex. That is especially noticeable in developing and developed countries. In that way it is well known that food supply chain of today is more and more globalized with certain food items that are produced, transformed and consumed in very different parts of the world. However, there are different types of food chain from traditional food systems in which consumers rely on minimally processed seasonal foods, collected or produced for self-consumption or sold mainly through informal markets, to the modern ones. The latest are characterized by more diverse food options all year long, and by processing and packaging to extend food’s shelf life (HPLE, 2017).

Whatever the case may be, it is necessary to ensure that food chains will provide sufficient food to all people at all times to meet their dietary needs for a productive and healthy life as well as to satisfy the consumer requirements.

To achieve food security for all, a multidimensional and integrated global strategy is necessary (Godfray el al., 2010). The responsibility for the supply of food that is safe, healthy and nutritious is shared along the entire food chain, by all involved with the production, processing, trade and consumption of food. This is what FAO defines as the **food chain approach** and it encompasses the whole food chain from primary production to final consumption (FAO, 2003). The food chain approach differs from the traditional model where it requires all actors in the food chain recognizing that primary responsibility lies with all those who produce, process, and trade in food. This approach is meant to ensure the production and supply of safe food products. Likewise, the relevant information regarding the safety of food should be provided to the next party in the food chain.

But it is also true as we have seen above, that at present, around one-third of the food that is produced for human consumption, is at the same time lost or wasted along the food chain from production to consumption. Accordingly,

food is lost or wasted throughout the entire supply chain, from initial agricultural production down to final household consumption. In medium- and high-income countries food is to a significant extent wasted at the consumption stage. Significant losses also occur early in the food supply chains in the industrialized regions. In low-income countries food is lost mostly during the early and middle stages of the food supply chain; much less food is wasted at the consumer level (FAO, 2011).

Food loose and waste (FLW) impact food security and nutrition by different ways. First, it means a reduction of availability of food. Second, it may have a negative impact on food access. This is the case not only for those involved in production and processing operations that face food loose and waste in relation to economic and income losses but also for consumers due to the increase of food prices that may occur as a result of FLW. Finally, a longer-term effect on food security resulting from the unsustainable use of natural resources on which the future production of food depends (HPLE, 2014).

Figure 1. The Farm to Fork strategy for a fair, healthy and environmentally-friendly food system (https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

Changes in the way that food is produced, stored, processed, distributed, accessed and consumed are required to face the challenge of feeding the food demand from a larger population to it supply but doing so in ways that are environmentally and socially sustainable and ensuring that the world's poorest people are no longer hungry (Godfray el al., 2010).

Identifying the causes of food loose and waste is primordial to apply solutions to reduce them, and priorities for action. In addition, it also requires an integrated perspective along the food chain and to consider any action at one

specific stage as part of a whole (HPLE, 2014). Since the different stages of the food chain are all connected, the decisions made by the many actors at any stage have implications for others. In fact, food loose and waste happening at one stage of the food chain can have their cause at another stage.

It is possible to be hundreds of different causes of food loose and waste, the importance of which may vary greatly according to the produce and the context, and the stage of the food chain considered. What is being analyzed here, are those related with food wasted at the consumption stage and so mainly related to the loss of food's attributes.

Food products are marketed as a composite of attributes or characteristics that have significance in determining the degree of acceptability of that product to the consumer. That is food quality. The entire list of the attributes that defines food product's quality and affect consumer's choice for a product may be really extensive. The importance of such characteristics varies according to the circumstances and also among customers. Therefore, there is not a single list of all attributes of food quality, though they are usually subdivided into five categories: food safety, nutritional, value, packaging and process attributes.

- Food safety is the assurance that the food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. Food safety assurance involves the prevention and control of hazards which may occur in the food.

- Nutritional attributes refers to maintaining nutrient levels in food, using ingredients and formulating foods with nutritional profiles that contribute to consumer interest in healthful diets.

- Value attributes desired by consumers extend beyond sensory characteristics, such as taste, aroma, palatability and appearance to include purity, consumer utility and economic advantage, involving attributes such as convenience, packaging and shelf-life.

- Packaging includes package materials, labeling and other information that is provided as for example handling and cooking instruction

- Process attributes refers to the circumstances of food processing such as animal welfare, the use of biotechnology, the environmental impact of the worker safety.

Food quality is a central issue in today's food economics and the last few decades testify that there is an increasing consumers' concerns for food safety and quality and healthier lifestyles as well as environment care. But also, food waste is a major global challenge not only from an ethical and social point of view, but also from environmental and economic ones.

Furthermore, it represents an inefficient use of the scarce resources used to produce it, such as land and water (FAO, 2013; Caldeira et al., 2019).

Working to minimize food loose and waste also contributes to make the food chain more sustainable. A sustainable food value chain is defined as “the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources” (FAO, 2014).

Despite of all the efforts that are made, we cannot forget that foods are perishable and that there are many factors that can deteriorate the quality and safety of food products shortening their "shelf life”.

1.2 | Shelf-life of foods

Along the food chain, from the point of primary production to consumption food attributes may change. These changes can either lead to a more desirable product, as for example the achieve of the appropriate level of ripeness in fruits but they can also deteriorate or contaminate food products so that they are rejected or even be responsible of food poisoning.

> Shelf life is a term frequently used in different ways. Generally speaking it can be said that shelf life of food products refers to the period for which they can be used while maintaining the food quality, provided any stated storage conditions have been followed.

The shelf life of a product begins from the time the food is prepared or manufactured and during this time it must preserve its sensorial, chemical, physical and microbiological.

Depending on their shelf life food may be classified as:

- **Stable or non-perishable food**. These are food products that have been treated and/or which contain less than 12% of free water so that they that can be stored for a long period even of several years or longer. Sugar, flour, canned food or dry beans are some examples of non-perishable foods.

- **Semi-perishable**. These are foods having lower than 60% of free water or containing some ingredients as acids or sugar, able to control microbial growth. These food items may therefore be preserved for long time (about six months) if they are properly handled and preserved. Cheeses, potatoes and apples are examples of semi-perishable food items.

- **Perishables**. These are food products that are easily spoiled. Therefore its shelf life usually ranges from several days to about three weeks if

specific conservation processes are not used. Milk and dairy products, eggs, meats, poultry, and seafood are examples of this kind of foods.

The way and the rate in which food deteriorates vary depending on the product and it can be due to several circumstances. Extrinsic factors, such as relative humidity or storage temperature may influence the shelf stability and perishability of food but it is also influenced by intrinsic factors as the formulation of ingredients, the methods of processing or the type of packaging. Therefore, the use of appropriate processing, packaging and storage techniques among other good practices, can enhance food product's quality.

However, food safety and quality standards imposed by supermarkets and regulators may lead to the discarding of food that is still safe for human consumption, representing an enormous waste of natural resources (FAO, 2017).

It is therefore necessary to understand the causes that shorten the shelf-life of food and the measures to deal with them. Along with the understanding of the information that is depicted in the food labelling it will help to develop strategies to reduce food waste.

In summary…

Food quality is the group of attributes or characteristics that have significance in determining the degree of acceptability of consumer. The loss of food's attributes is a cause for food waste.

To guarantee food quality preventing from food waste is a shared responsibility along the entire food chain: primary production stage, processing and manufacturing in the food industry, distribution and retail and finally, consumers.

2.| Food labelling: food information to consumers

Food labels are an important information tool for consumers as they communicate facts about the product or the production process. The food business operator is responsible for the food information in accordance with law requirements. Showing the right information in the labels, and convey this clearly, helps to ensure that consumers will not misinterpret it, and that food will be stored and used properly being safe and fit to eat. This will significantly contribute to the reduction of food thrown away from our homes due to it not being used in time and also help surplus food redistribution (Weinrich and Spiller, 2016; WRAP et al., 2019).

2.1 | Mandatory particulars

Regulation (EU) No 1169/2011, commonly known as the Food Information to Consumers Regulation, establishes the general principles, requirements and responsibilities governing food information, and in particular food labelling. It lays down the means to guarantee the right of consumers to information and procedures for the provision of such information. The provision of food information will provide a high level of protection of consumer's health and interests by providing a basis for them to make informed choices and to make proper use of food.

The following information must be present on all European Union food labels:

- **The name of the food**

The name of the food must be clearly stated on the packaging and not be misleading.

If there is a name prescribed in law this must be used. In the absence of a legal name, a customary name can be utilized. This might be a name that has become commonly understood by people and established over time. If there is no customary name or it is not used, a descriptive name of the food must be provided. This must be sufficiently detailed to inform the purchaser of the true nature of the food.

The name of the food needs to include an indication of the physical condition of the food e.g. powdered, refrozen, concentrated, smoked in all cases where omission of such information could mislead the consumer.

- **The list of ingredients**

If a food product has two or more ingredients (including water and additives), they must be listed under the heading 'Ingredients'. They will appear in descending order of weight, with the main ingredient first, as recorded at the time of their use in the manufacture of the food.

Some foods are exempt from the need to display an ingredient list, such as fresh fruit and vegetables which have not been peeled, cut or treated; carbonated water; fermentation vinegars; cheese, butter, fermented milk and cream, to which no ingredient has been added other than lactic products, food enzymes and microorganism cultures essential to manufacture; or foods consisting of a single ingredient where the name of the food is identical to the ingredient name, or the name of the food enables the nature of the ingredient to be clearly identified.

- **Allergen information**

Where a food product contains any of the substances causing allergies or intolerances required to be declared by law (Table 1), these ingredients must be emphasized within the ingredients list using a different font, style, background color or by bolding the text. In the absence of a list of ingredients, the indication of these substances shall comprise the word “contains” followed by the name of the substance. This enables consumers to understand more about the ingredients in packaged foods and is helpful for people with food allergies and intolerances who need to avoid certain foods.

Table 1. Substances causing allergies or intolerances (Regulation (EU) No 1169/2011)

Cereals containing gluten	Milk and products thereof (including lactose)
Crustaceans and products thereof	Molluscs, and products thereof
Peanuts and products thereof	Mustard and products thereof
Eggs and products thereof	Sesame seeds and products thereof
Fish and products thereof	Lupine and products thereof
Nuts, including Brazil nuts, pistachios, almonds, hazelnuts, walnuts, pecans, cashews and macadamia nuts	Sulphur dioxide and sulphites at concentrations of more than 10 mg/kg or 10 mg/litre
Soybeans and products thereof	Celery and products thereof

- **Minimum durability date, “use by” date and date of freezing**

Food labels must be marked with either a “best before” or “use by” date so that it is clear how long foods can be kept and how to store them. The date of freezing or the date of first freezing shall also be indicated in the case of frozen meat, frozen meat preparations and frozen unprocessed fishery products.

- **Any special storage conditions and/or conditions of use**

In cases where foods require special storage conditions and/or conditions of use, those conditions shall be indicated.

To enable appropriate storage or use of the food after opening the package, the storage conditions and/or time limit for consumption shall be indicated as well, where appropriate.

Open life is the period of time during which a food will remain safe and/or of a suitable quality for consumption after the primary product packaging has been opened and it is stored as instructed (WRAP et al., 2019).

- **Instructions for use**

Instructions on how to prepare and cook the food appropriately must be given on the label if they are needed.

- **Nutritional declaration**

The mandatory nutrition declaration provides values for food energy and fat, saturates, carbohydrate, sugars, protein and salt. It can be supplemented with an indication of the amounts of one or more of the following: monounsaturated, polyunsaturated, polyols, starch, fiber, and vitamins or minerals.

- **The name and address of the food business operator**

The food business operator responsible for the food information shall be the operator under whose name or business name the food is marketed.

These mandatory particulars described above are closely related to the prevention of food waste. The rest of mandatory information that must be depicted in prepacked foods to the final consumer is the net quantity of the food, the quantity of certain ingredients, the alcoholic strength in beverages containing more than 1.2 % by volume of alcohol, as well as the country of origin or place of provenance. We must take into account that pack size conditions compulsory labelling requirements. If largest surface area is <10cm2 then only the name of the food, allergen labelling, date mark and quantity declaration are required.

Directive 2011/91/EU regulates another mandatory information related to indications or marks identifying the lot or batch to which a foodstuff belongs.

Lot means a batch of sales units of a foodstuff produced, manufactured or packaged under practically the same conditions.

Indication of the lot to which a foodstuff belongs meets the need for better information on the identity of products. It is therefore a useful source of information when foodstuffs are the subject of dispute, or constitute

a health hazard for consumers or need to be redistributed, and it is required in order to facilitate traceability. It is usually positioned next to the durability indication, and shall be preceded by the letter “L” except in cases where it is clearly distinguishable from the other indications on the label. When the date of minimum durability or “use by” date appears on the label, the indication lot need not appear on the foodstuff, provided that the date consists at least of the uncoded indication of the day and the month in that order.

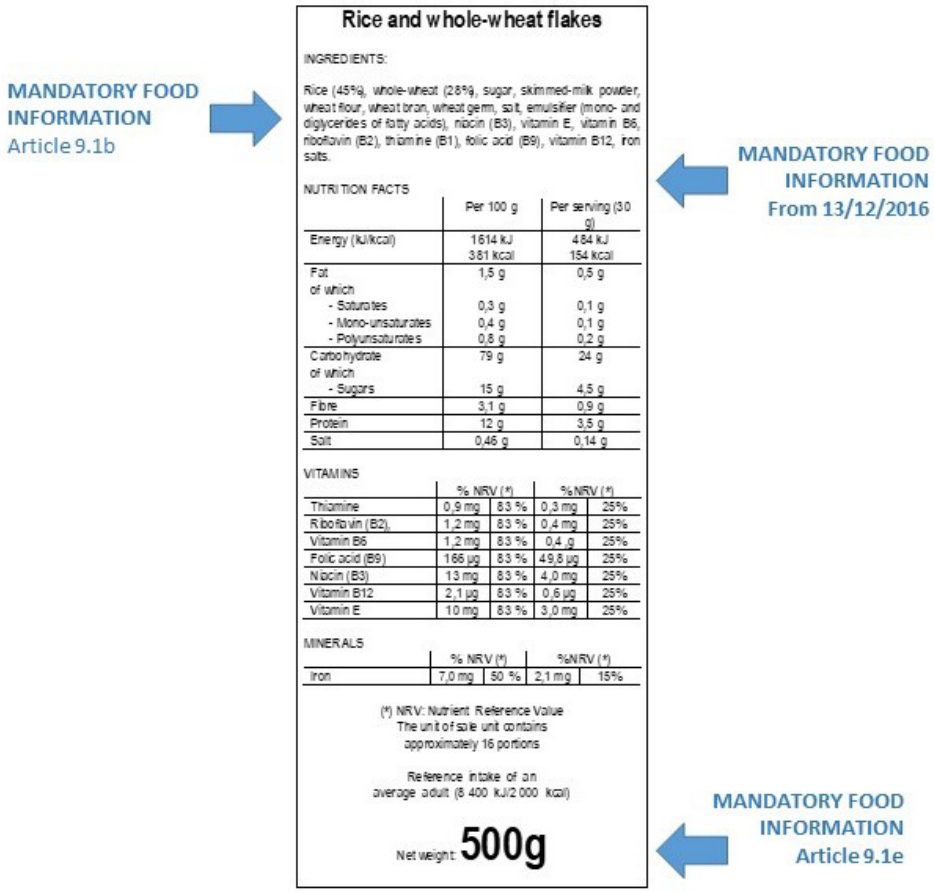


Figure 2. Food labelling
(http://eletiquetadocuentamucho.aecosan.msssi.gob.es/etiquetado.html)
Translation: ZERO_WASTE project

How to display mandatory information on packaging and labels

Mandatory food information must be easy to see; be clearly legible and be difficult to remove, where appropriate; not be in any way hidden, obscured, detracted from or interrupted by any other written or pictorial matter; and should not require consumers to open the product to access the information.

All mandatory requirements shall be printed on the package or on the label in characters using a font size where the x-height is equal to or greater than 1.2 mm to ensure clear legibility (Figure 3). Exemption for smaller packs where largest surface area is less than 80 cm2 “x height” of 0.9 mm.

Figure 3. Minimum font size of mandatory food labelling information (Regulation (EU) No 1169/2011; FDII, 2013).

2.2 | The date of minimum durability (“Best before”) and the “Use by” date

Misinterpretation by consumers of the meaning of the "best before" and "use by" dates can contribute to household food waste. The European Commission estimates that up to 10% of the 88 million tons of food waste generated annually in the European Union is linked to date marking on food products. Clear and correct information on packaging and a better understanding and use of date marking on food by all actors concerned, can prevent and reduce food waste while food safety is ensured (EFSA, 2020).

Regulation (EU) No 1169/2011 defines **date of minimum durability of a food** as the date until which the food retains its specific properties when properly stored. The date of minimum durability shall be preceded by the words **“Best before …”** when the date includes an indication of the day, or **“Best before end …”** in other cases. The words referred shall be accompanied by either the date itself, or a reference to where the date is given on the labelling. If need be, these particulars shall be followed by a description of the storage conditions which must be observed if the product is to keep for the specified period.

The date shall consist of the day, the month and possibly, the year, in that order. However, in the case of foods not being kept for more than 3 months, an indication of the day and the month shall be sufficient; for foods which will keep for more than 3 months but not more than 18 months, an indication of the month and year shall be enough; and those foods which will keep for more than 18 months, an indication of the year shall be adequate.

“Best before” date refers to quality rather than safety. Until this date, a foodstuff is expected to maintain its taste, aroma, appearance, vitamin content etc., when it has been stored appropriately and the package unopened, and after which it will not be in optimal conditions. It is important to note that the food will be safe to eat after this date but may not be at its

best. Common sense can be used, and if the food or drink is organoleptically acceptable to the consumer after the best before date, then it can be eaten.

On the basis of Regulation (EU) No 1169/2011, the indication of the date of minimum durability shall not be required for some foods such as fresh fruit and vegetables which have not been peeled, cut or similarly treated; wines and beverages containing 10% or more by volume of alcohol; bakers' or pastry cooks' wares which are normally consumed within 24 hours of their manufacture; vinegar; cooking salt; solid sugar; confectionery products consisting almost solely of flavoured and/or coloured sugars; or chewing gums and similar chewing products.

In the case of foods which, from a microbiological point of view, are highly **perishable** and are therefore likely after a short period **to constitute an immediate danger to human health**, the date of minimum durability shall be replaced by the **"use by" date**. Food can be eaten up to the end of this date but not after, even if it looks and smells fine and it has been stored correctly, because it shall be deemed to be unsafe (harmful microorganisms are odorless and flavourless).

Regulation (EU) No 1169/2011 establishes that the data will be expressed by the words "use by …" indicating the date itself, or, a reference to where the date is given on the labelling, The date shall consist of the day, the month and, possibly, the year, in that order and in uncoded, and shall be followed by a description of the storage conditions which must always be observed.

In summary…

The term **"Best before"** indicates the period for which a food can reasonably be expected to retain its optimal condition and so relates to the quality of the food. Best before dates appear on a wide range of foods including frozen, dried and tinning foods.

The term **"Use by"** should only be applied on foods which, from a microbiological point of view, are highly perishable and are therefore likely, after a short period, to constitute an immediate danger to human health. It will appear on food that goes off quickly such as ready-to-eat salads, fresh meat or fish, among others.

Figure 4: https://ec.europa.eu/food/system/files/2020-06/fw_eu-actions_date-marking_infographic_en.pdf

How date marking is utilised by food business operators and regulatory authorities in managing the supply chain can also have an impact on food waste. For example, the approaches followed by food business operators in defining whether to utilise a "use by" or "best before" date, market practices such as the amount of shelf life required by retailers on product delivery, or further redistribution of foods past the "best before" date, can influence the generation of food waste. In this context, EFSA has developed a tool to help food business operators decide when to apply the “use by” or “best before” date to their products, that is based in a decision tree with a series of questions to be answered. Questions range from whether date marking requirements for a food category are already regulated by legislation, whether a product undergoes any treatment to eliminate hazards, whether it is handled again before packaging, and its characteristics and storage conditions (Figure 5). Assisting them in their choice of the type of date and on setting the appropriate shelf-life, storage conditions and open life instructions contribute to the better management of foods (EFSA, 2020).

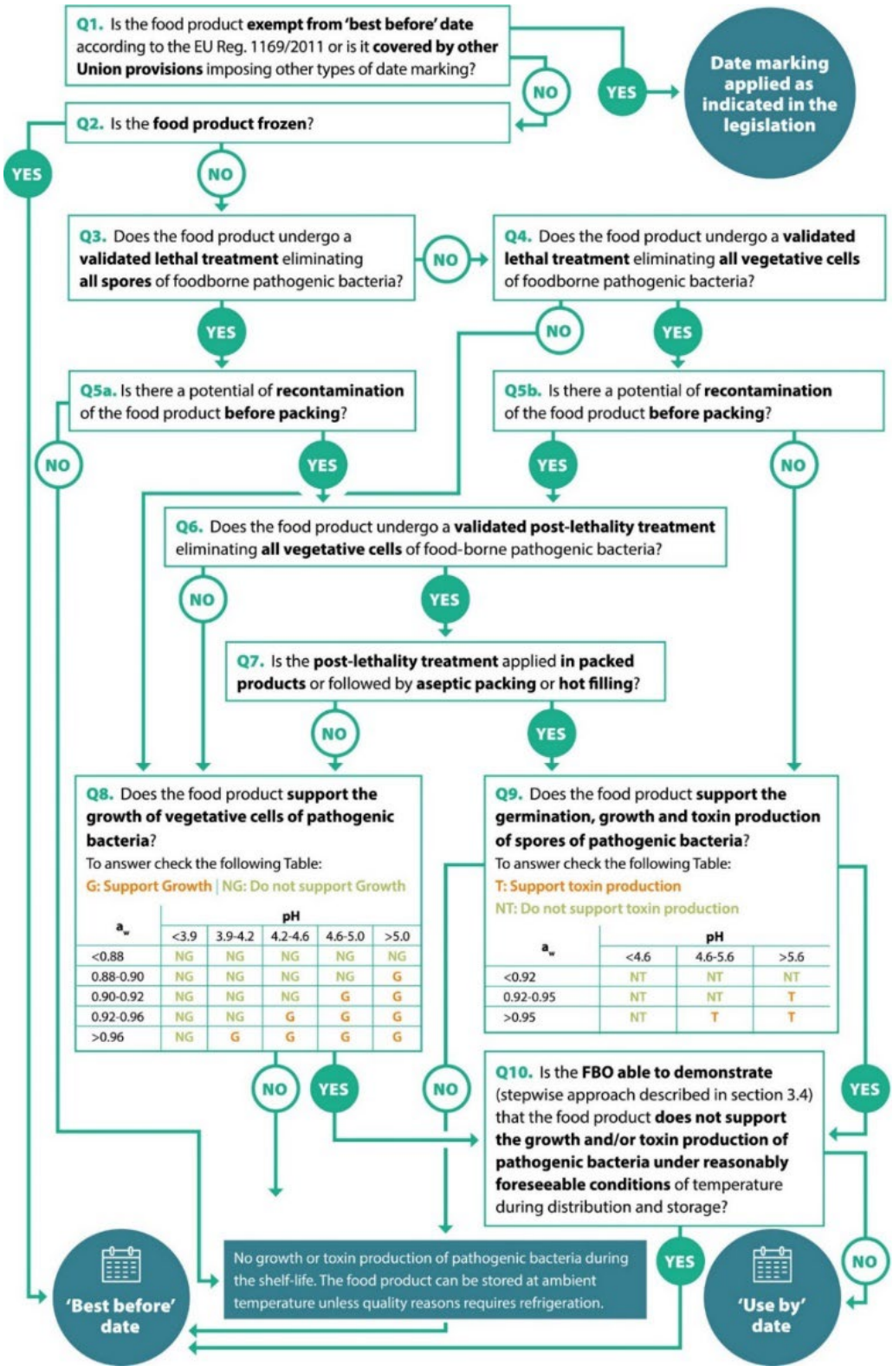


Figure 5. Decision tree on the appropriate date marking for temperature controlled prepacked foods (EFSA, 2020).

2.3 | Shelf-life studies

Food business operators are legally responsible for the determination of the date of minimum durability of the foodstuffs they place on the market. Shelf-life studies allow establish this date with certainty, and to document that the food will remain safe and/or will retain its quality until the end of said shelf-life. Shelf-life analysis include chemical, sensory, and microbiological testing of food products to examine how they change with time and other environmental factors. Different aspects like the product ingredients, packaging, processing, and storing conditions are considered (Giménez et al., 2012).

As well, and regarding food microorganisms, the European law establishes that the food business operators shall conduct studies in order to investigate compliance with the microbiological criteria throughout the shelf-life of the food product they manufacture (Regulation (EC) No 2073/2005). In particular, this applies to ready-to-eat foods that are able to support the growth of Listeria monocytogenes and that may pose a risk for public health. These studies include:

- Specifications for physico-chemical characteristics of the product, such as pH, aw, salt content, concentration of preservatives and the type of packaging system, taking into account the storage and processing conditions, the possibilities for contamination and the foreseen shelf-life.
- Consultation of available scientific literature and research data regarding the growth and survival characteristics of the microorganisms of concern.
- Predictive mathematical modelling established for the food in question, using critical growth or survival factors for the microorganisms of concern in the product.
- Tests to investigate the ability of the appropriately inoculated microorganism of concern to grow or survive in the product under different reasonably foreseeable storage conditions.
- Studies to evaluate the growth or survival of the micro-organisms of concern that may be present in the product during the shelf-life under reasonably foreseeable conditions of distribution, storage and use.

There is not a generic method to estimate and establish the shelf-life of foods. The most commonly methods used are the following:

- **Direct method or standard shelf-life study**

This method is a real-time study that consist of storing the product under similar conditions to those that it will be during commercialization, monitoring its evolution in different intervals of time. It creates a very accurate estimation of the time it takes for a product to deteriorate.

- **Accelerate shelf life study**

In this type of studies, the food product is conditioned and stored at elevated temperature and/or humidity, and the product quality changes are analyzed at a specific sampling rate. The accelerated shelf life study can be two to four times faster than the standard shelf life study, it is very versatile and allow for the comparison of different scenarios.

- **Microbiological challenge test**

A challenge test is a practical study to determine the behavior of relevant microorganisms if they should be present in a food product. It implies the experimental inoculation of a known concentration of the microorganism into the food product and aims at evaluating its evolution under the foreseen storage conditions.

- **Predictive microbiology**

This methodology studies the response of microorganisms in foods under different environmental conditions, based on mathematical and statistical models, in order to predict the behaviour of the microorganisms in the product.

- **Survival method**

This method is based on the opinion of the consumers, and the probability of them accepting a product beyond a certain storage time. Although it is not a method to accurately estimate the shelf life, it can be complementary to other tests.

3.| Nutrition. Food composition

3.1 | Nutrition

World Health Organization (WHO) states that access to sufficient amounts of safe and nutritious food is key to sustaining life and promoting good health. With the ingestion of food, our organism absorbs the minerals, vitamins, fats, proteins, carbohydrates and water providing the energy and the necessary elements to support a healthy life.

The contents of a healthy diet varies depending on the nutritional status and dietary needs of a person. The WHO recommendation for a healthy diet for an adult is the following (Lindgren et al., 2018; FAO and WHO, 2019): the basic diet should consist of fruits, vegetables, legumes, nuts and whole grains, with a daily intake of 400 g of fruits and vegetables; free sugars and fats should be less than 10% and 30% of total energy intake, respectively; unsaturated fats are preferable to saturated fats. Industrial trans fats, found in processed food should be avoided; and the intake of salt should be less than 5 g per day.

It is important to achieve food requirements of the population and to do it within a sustainable development framework. **Sustainable healthy diets** are dietary patterns that promote individuals' health and wellbeing, have low environmental pressure and impact, are culturally acceptable, accessible, affordable, safe, equitable, and reduce food loss and waste (FAO and WHO, 2019). However, our world is rapidly changing, and the increment of food consumption by a growing population, together with the changes in dietary habits, constitute an important challenge for the global food system (Lindgren et al., 2018; Al-Thani et al., 2020).

European food is already a global standard for food that is safe, nutritious, abundant, and of high quality. This is the result of the European Union policy to protect human health, to improve nutrition and healthy diets, to strength food systems and to reduce food waste. Food processors influence consumers' dietary choices through the types and nutritional composition of the food they produce, their production methods, and marketing practices. On the other hand, consumers continuously become more aware that proper food is directly connected to their wellbeing and can prevent nutrition-related diseases (European Commission, 2020; Galanakis, 2021).

The provision of clear information that makes it easier for consumers to choose healthy diets will benefit their quality of life, and reduce health-related costs. Related to this, the European Commission has proposed harmonized mandatory nutrition labelling to food products (Regulation (EU) No 1169/2011).

3.2 | Food composition

Food provides the energy and nutrients we need to be healthy. Therefore, food composition is critical for nutrition, health promotion, disease prevention, and food production (Pehrsson and Haytowitz, 2016).

Energy is required continuously for normal organ function, metabolic homeostasis, thermoregulation and physical activity. Food energy is the energy released from carbohydrates, fats, proteins, and other organic compounds contained in food. The unit of energy is the Joule (J). One calorie (cal) is equal to 4.2 Joules (Costa-Pinto and Gantner, 2020).

Nutrients can be classified into macronutrients (proteins, lipids and carbohydrates), that are essential compounds ingested in large amounts (g), and micronutrients (vitamins and minerals) because small amounts of these components are needed for the body (mg or µg).

To know more… (1)

On the basis of Regulation (EU) No 1169/2011 regarding food information to consumers, mandatory information shall include information on food nutritional characteristics so as to enable consumers, including those with special dietary requirements, to make informed choices. The mandatory nutrition declaration shall include the following: energy value, and the amounts of fat, saturates, carbohydrate, sugars, protein and salt.

The content of the mandatory nutrition declaration may be supplemented with an indication of the amounts of one or more of the following: mono-unsaturates, polyunsaturates, polyols, starch, fibre, and vitamins or minerals present in significant amounts (Table 2). As a rule, for vitamins and minerals a significant amount means 15% of the nutrient reference values (NRVs) per 100g or ml for products other than beverages; 7.5% of the NRVs per 100ml for beverages.

Table 2. Vitamins and minerals which may be declared and their nutrient reference values (NRVs) (Regulation (EU) No 1169/2011)

Vitamins	NRVs	Minerals	NRVs
Vitamin A (µg)	800	Potassium (mg)	2 000
Vitamin D (µg)	5	Chloride (mg)	800
Vitamin E (mg)	12	Calcium (mg)	800
Vitamin K (µg)	75	Phosphorus (mg)	700
Vitamin C (mg)	80	Magnesium (mg)	375
Thiamin (mg)	1.1	Iron (mg)	14
Riboflavin (mg)	1.4	Zinc (mg)	10
Niacin (mg)	16	Copper (mg)	1
Vitamin B6 (mg)	1.4	Manganese (mg)	2
Folic acid (µg)	200	Fluoride (mg)	3.5
Vitamin B12 (µg)	2.5	Selenium (µg)	55
Biotin (µg)	50	Chromium (µg)	40
Pantothenic acid (mg)	6	Molybdenum (µg)	50
		Iodine (µg)	150

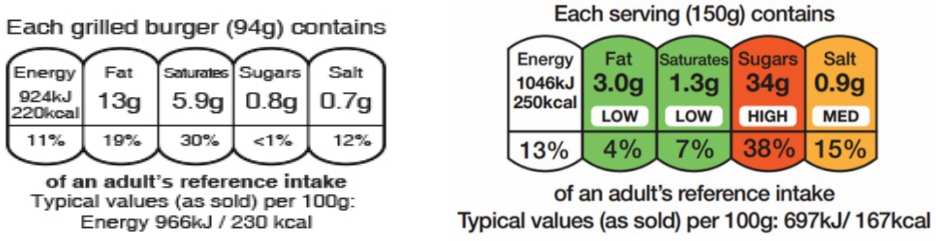
The declared nutritional data shall be average values based on the manufacturer's analysis of the food; a calculation from the known or actual average values of the ingredients used; or a calculation from generally established and accepted data. The presentation of nutrient declaration shall be as shown in Table 3, and shall be expressed per 100 g or per 100 ml. When provided, the declaration on vitamins and minerals shall also be expressed as a percentage of the reference intakes. The particulars shall be included in the same field of vision, presented together in a clear format and shall be presented in tabular format, if there is enough space.

Table 3. Expression and presentation of nutritional declaration (Regulation (EU) No 1169/2011)

Energy	kJ/kcal
Fat **of which**	g
- **saturated**	g
- **mono-unsaturated**	g
- **polyunsaturated**	g
Carbohydrate **of which**	g
• **sugars**	g
• **polyols**	g
• **starch**	g
Fibre	g
Protein	g
Salt	g
Vitamins and minerals	The units specified in Table 2

This Regulation establishes which foods are exempted from the requirement of the mandatory nutrition declaration. These are unprocessed products with a single ingredient or category of ingredients; processed products have been subjected to is maturing and comprise a single ingredient or category of ingredients, waters intended for human consumption, herbs and spices, salt, table top sweeteners, coffee extracts and chicory extracts, whole or milled coffee beans, herbal and fruit infusions, tea or fermented vinegars, among others.

The energy value and amounts of certain nutrients may be voluntarily repeated, using other forms of expression presented using graphical forms or symbols in addition to words or numbers provided. This highlighted nutrition information can help consumers make healthier food choices. Figure 6 shows different forms of nutritional expression. Graphical expression in Figure 6A is without colors, and Figure 6B shows a traffic light label, from green, which is good, amber, which is caution, or red, which is not good.



A B

Figure 6. Different forms of nutritional expression.
A https://labellingtraining.food.gov.uk/module5/overview_4.html
B https://sidlaurea.com/2021/03/20/game-changers/

The Nutri-Score is a voluntary front-of-pack nutrition label that converts the nutritional value of products into a code based on a five-colour scale going from dark green to red, associated with letters from A (being a preferable score) to E (being a detrimental score), respectively. This nutritional scoring method was developed by the British Food Standard Agency. Each product is awarded a score based on a scientific algorithm taking into account the nutrients to avoid (energy, sugars, saturated fatty acids, salt) and the positive ones (proteins, fibre, percentage of fruit, vegetables, nuts, rapeseed oil, walnut oil and olive oil). The algorithm gives points for each element in the nutrition table (per 100 g or ml), and the subtraction of the positive points from the negative ones converts the result to the Nutri-Score code (Figure 7).

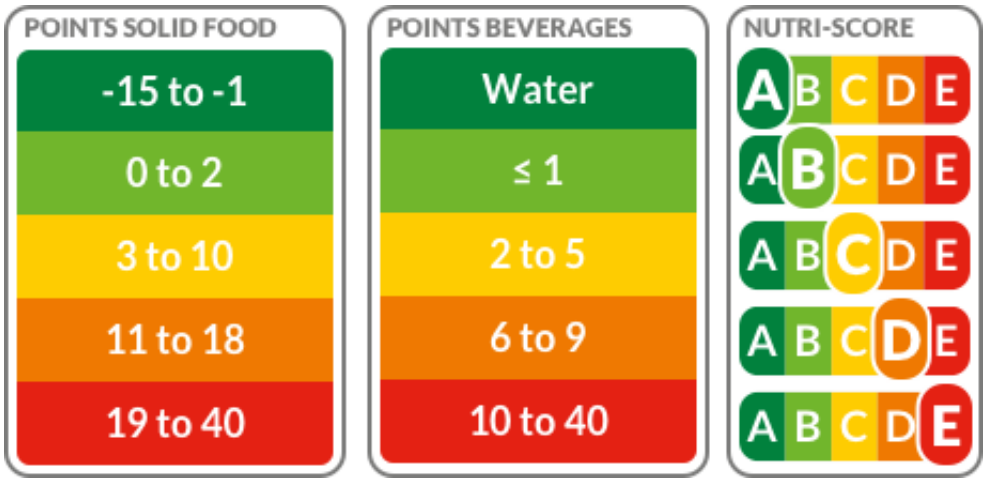


Figure 7. Nutri-Score voluntary front-of-pack nutrition label
https://nutriscore.colruytgroup.com/colruytgroup/en/about-nutri-score/

3.2.1. Databases on food composition

Food composition databases are essential tools for food research, nutritional health care, food industry and for those fields where the information on nutritional composition of foods is required (Kapsokefalou et al., 2019). Detailed documentation concerning foods and their components is required. Hence, a constant effort is needed to keep the values up-to-date, improve their quality, and to extend the databases with new foods, new components and other food characteristics (Westenbrink et al., 2021; Ocké et al., 2021).

Important databases are:

- **BEDCA – Spanish Food Composition Database**: http://www.bedca.net/
- **European Union**: http://www.efsa.europa.eu/en/data/food-composition
- **EuroFIR – European Food Information Resource**: https://www.eurofir.org/food-information/food-composition-databases/

- **INFOODS – International Network of Food Data Systems:** http://www.fao.org/infoods/infoods/tablas-y-bases-de-datos/bases-de-datos-faoinfoods-de-composicion-de-alimentos/es/
- **USDA – Food Composition Database**: https://fdc.nal.usda.gov/ndb/

3.2 | Food composition

Nutritional content can be affected during the growing, harvesting, storage, processing and cooking of food. Processes that expose foods to high levels of heat, light or oxygen cause the greatest nutrient loss. On the other hand, there is an important waste of valuable nutrients through food losses and waste (HLPE, 2014; Gustavsson et al., 2011). In this case, “nutrient loss” refers to the nutrient content embedded within FLW (Spiker et al., 2017).

Regarding nutrient loss, and considering that different food items differ widely in their nutritional content, quantifying the food waste in caloric terms, as usually practised, does not provide the true extent of damage done, so the losses of essential macro and micronutrients should also be considered (Chen et al., 2020). As an example, a project funded by the European Commission Framework Programme, examined waste of nine indicator food products (apples, tomatoes, potatoes, bread, milk, beef, pork, chicken, and whitefish) in European Union member countries, reporting substantial losses of vitamin A, beta carotene, vitamin C, fibre, iron, zinc, n-3 fatty acids, lysine, and methionine (FUSIONS, 2016).

It has been observed that the food waste of high-income countries of North America and EU embed many times higher nutrient losses on a per capita level than low-income countries (Chen et al., 2020). All the world's hungry people could be lifted out of energy or protein malnourishment on less than a quarter of the wasted food in the USA, UK, and Europe (Stuart, 2009). Reducing FLW may, thus, present a great opportunity in enhancing the sustainability of the food system and simultaneously improve food security and nutrition (Lindgren et al., 2018).

4.| Food spoilage

Food spoilage may be defined as a process or change which renders a product undesirable or unacceptable for consumption (Nychas and Panagou, 2011). This complex ecological phenomenon results when microbiological, chemical, or physical changes occur. These mechanisms are not necessarily mutually exclusive since spoilage caused by one mechanism can stimulate another (Amit et al., 2017). Different factors will define the mechanism that will dominate this process.

From the above considerations it follows that in general, the term spoilage is regards as negative. However, some process conducting to food spoilage are also needed for acquiring the characteristic food sensorial properties. In this context, it must be underlined that spoiled food can be safe but not fit for consumption. Conversely, it is also possible that food with appropriate organoleptic and nutritional properties represents a risk to public health.

To avoid food spoilage it is necessary to understand the causes and mechanisms conducting to food deterioration, which are described below.

4.1 | Factors affecting food spoilage

Factors affecting spoilage of foods may be divided into intrinsic factors that are endogenous to the food and extrinsic parameters that refer to those in the environment in which a food is produced and/or stored.

Intrinsic factors include food structure and composition, water activity, pH and redox potential.

- Therefore, some foods may pose some **structures** such as skin of fruits and vegetables, testa of seeds, and the shell, cuticle, and membrane of egg, which act as mechanical barriers protecting them from deterioration (Lianou et al., 2016). In the same way as food structure, **food composition** is a key parameter in relation to food spoilage. In fact, nutrient formulation may determine among others the water content, pH value, and also influences the growth of the most suitable species of microorganisms.

- **Water activity (aw)** is an indicator of the amount of free water in food, that is, the water in a food that is not bound and so it is available to supports microbial growth and to participate in and supports chemical and enzymatic reactions and spoilage processes.

  Microorganisms have a limiting water activity level below which they are not able to grow. The optimum for most microorganisms is in the range 0.9950.980. By comparison, water activity of food may vary from less than 0,60 in dehydrated products to more than 0,98 in fresh ones. These

values are used to predict the survival of microorganisms in a food product. However, the aw of a food may not be a fixed value; it may change over time, or may vary considerably between similar foods from different sources (FDA, 2012).

- **pH (hydrogen ion concentration, relative acidity or alkalinity)** is related to the concentration of hydrogen ions, releasing from the acids ingredients that dissociate in water. On one side, pH values in foods vary according to their composition. On the other side, microorganism only can grow at certain pH values. In that way, induced or naturally-occurring acidification of food is used for controlling the growth of undesirable microorganisms.

- **Redox potential**, is related to the growth and survival of the microorganism as affected by the availability of oxygen.

  At this concern, aerobic microorganisms are those growing in the presence of atmospheric oxygen whereas anaerobic microorganism do it in the absence of free oxygen.

Extrinsic parameters are factors in the environment in which a food is processed and stored, notably temperature and relative humidity or atmosphere composition. Other factors such as exposure to light will be named along with the mechanisms of spoilage

- **Temperature** strongly influences microbial growth. There is a 'Danger Zone' which in general allows most microorganisms to grow rapidly. This zone refers to temperatures between 8°C and 60°C. When in the 'Danger Zone' bacteria can double in number every 20 minutes. After food being at this temperature for hours, the number of bacteria may be high enough to have severe consequences.

  Apart from that, temperatures may produce chilling injury in some foods.

- Relative **humidity (RH)** refers to the moisture content of the atmosphere and it directly affects the moisture content of food. The difference between the RH of the surrounding environment and the water activity (aw) of the food determines whether a food gains or loses moisture during storage. The higher the difference between aw and RH during storage, the more potential for moisture migration to or from the environment until equilibrium is reached (Kong and Singh, 2016).

- With regards to the **atmosphere composition** and according to what it has been explained before, the composition of gases in the environment surrounding the food can also have an effect in the microbial growth and the chemical reactions occurring in food. In this sense, elevated

concentrations of carbon dioxide (CO_2) tend to slow the growth of microorganism.

To know more … (2)

4.2 | Food spoilage mechanisms

4.2.1. Physical spoilage

- **Physical injury** is a very important cause of loss in fruits and vegetables. Damage in these products may be produced by different forces such as surface abrasion or handling of packaging at which food products may be subjected (Kong and Singh, 2016).

  One of the most important food components is water and changes in water content is a common cause of degradation of food products. Moisture loss causes fresh produce to wilt and shrivel, and to experience increased senescence. For frozen foods, moisture migration from the inside to surface could cause freezer burn (Kong and Singh, 2016). Moisture exchange is as well a frequent cause of changes in texture of food. Examples include dried foods such as breakfast cereals and chips becoming soggy instead of crunchy after gaining moisture while soft texture foods becoming hard and brittle when decreasing their water content.

  Since many reactions need water to be done, increasing food water content not only affects its sensory attributes but also can promote chemical changes or microbial growth.

  Other substances may be transferred from or to food resulting in undesirable food changes as for example the loss of CO_2 in carbonated drinks or the adsorption of flavourings coming from packaging materials.

- **Crystallization** is an important thermo-physical phenomenon through which a substance precipitates due to supercooling or supersaturation conducting to the formation of a crystalline lattice structure (Kiani and Sun, 2011).

- Some crops, specially tropical fruits and vegetables are sensitive to **chilling injury**, which generally occurs at temperatures of 5-15 ºC. Effects of chilling injury include pitting, water soaking, discoloration, development of off-flavours, accelerated senescence, or ripening/over-ripening (Singh and Anderson, 2016).

4.2.2. Physical spoilage

Chemical and biochemical food spoilage occurs when different components in the food react with each other or with some added component which alter the food's sensory characteristics. The most important ones include: oxidation; hydrolysis, enzymatic browning and non-enzymatic browning.

- **Oxidation** occurs when food comes in contact with oxygen in the air. This immediately begins the decaying process, affecting the food's taste, colour, and nutritional value. Many essential nutrients are oxidized in the presence of air resulting in their reduced efficacy.

- **Hydrolysis** of a chemical compound consists of the fragmentation of their molecules under suitable conditions, in the presence of water. Different hydrolytic reactions may cause food deterioration. For example, in carbonated drinks containing aspartame, hydrolysis reactions under ideal pH and temperature will reduce sweetness.

- **Non-enzymatic browning**, which is also known as Maillard reaction, is an ubiquitous reaction taking place in heat-treated foods and also those foods stored during long time at room temperature. It is desirable in products where a brown colour and a special aroma are expected, such as coffee, bread, and cooked meat but it is also a primary cause of food spoilage in others, like milk. Thus its contribution to the quality of the product is product-dependent.

- The **Enzymatic browning** suffered by many fruits (peeled and sliced apples and bananas) and vegetables (cut lettuce and mushrooms) is one of the most important reactions that occur in these products. When food products are cut, peeled, diseased, or exposed to any abnormal conditions, cells lose their compartmentation, which brings about the release of enzymes from subcellular structures and phenolic compounds from the vacuole. Therefore it may occur the enzymatic oxidation of the phenolic compounds (substrate) initiated by several related enzymes, mainly the enzyme polyphenoloxidase (PPO), also known as phenolase. The reaction usually resulting in negative effects on colour (browning), taste, flavour, and nutritional value and is perceived as undesirable by consumers so it limits the shelf life of these kind of products.

4.2.3. Microbial food spoilage

Foods, particularly those with a high water and nutrient content and neutral pH values, are substrates ideally suited for the growth of microorganisms. Microbial food spoilage is the outcome of the biochemical activity of specific groups of microorganisms (molds, yeasts, or bacteria) resulting in final products with an inadequate shape or appearance, despite of they be safe. Microbial food spoilage is an important cause of food waste accounting for up to 25% of the post-harvest food supply. The microorganisms most often

associated with food spoilage are varied and depend highly on the type of food that is spoiled and the way that it has been processed and stored.

- **Bacteria** are responsible for some of the most rapid and evident spoilage events of proteinaceous foods such as meat, poultry, fish, shellfish, milk, and some dairy products (Petruzzi et al., 2017).

- **Molds and yeasts** can affect a wide range of products which have low pH or water activity (aw). Spoilage caused by molds and yeasts is often manifested by their visible growth on the surface of foods such as cheese and meat, as well as by fermentation of sugars in liquid and semiliquid products to produce acid, gas or alcohol or the development of off-odours and off-flavours (Huis in't Veld, 1996; Lianou et al., 2016)

  Mould spoilage can also be a food safety issue due to the production of mycotoxins or allergens by these moulds.

To know more …. (3)

5.| Food hazards

Safety is an intrinsic quality attribute of foods and it is strictly related to their suitability for human consumption. Unsafe food is a threat to human health and economies globally. Over 200 diseases are caused by eating food contaminated with bacteria, viruses, parasites or chemical substances such as heavy metals. This growing public health problem causes considerable socioeconomic impact though strains on health-care systems lost productivity, and harming tourism and trade (WHO, 2020).

Unsafe food is due to the presence of food hazards, that is, any agent with the potential to cause adverse health consequences for consumers. There are different type of food hazards that need to be considered: biological, chemical, physical, allergenic, nutritional and/or biotechnology-related. Food safety hazards may occur naturally, be unintentionally or intentionally introduced. They can also be introduced at any stage of the food chain. In any case, there are often no visual indicators regarding their presence in foods despite of they may lead to serious health impairment or fatality. As explained before, it is possible that food with appropriate organoleptic and nutritional properties represents a risk to public health.

The term **"contaminant**" that is frequently used to refer to food hazards is defined in legislation (Regulation (EEC) No 315/93) as any substance not intentionally added to food which is present in such food as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or as a result of environmental contamination.

- **Biological hazards** are microorganisms such as bacteria, viruses, yeasts, molds and parasites or they may produce toxin in the food chain that pose a threat to human health. The also include other biological hazards as prions. Biological hazards are of great concern to food industry because they are responsible for most of foodborne illness outbreaks.

To know more … (4)

- **Chemical contamination** of food can lead to acute poisoning or long-term diseases, such as cancer. Of most concern for human health are naturally occurring toxins including mycotoxins, marine biotoxins, cyanogenic glycosides and toxins in poisonous mushrooms. Also important are environmental contaminants such as the persistent organic pollutants (POPs) dioxins, which are unwanted by-products of industrial processes and waste incineration, and polychlorinated biphenyls (PCBs). Pollution of the air, soil and water is also responsible for contaminating

food with heavy metals such as lead, arsenic, cadmium and mercury. Also relevant are food contact materials, cleaning agents, processing-induced chemicals, food additives, pesticides and veterinary drug residues.

- **Physical hazards** involve glass, packaging, jewellery, pest droppings, screws, etc. which usually result from accidental contamination and /or poor food handling practices.

Chemical and biological hazards substantially differ in their characteristics, persistence, survivability and adverse health effects. In this way, microbiological pathogens are able to multiply in under favourable conditions, while this is not possible for chemical hazards. Moreover, microbiological pathogens can be eliminated or reduced after processing, while most often this is not the case for a chemical contamination.

Ensuring food safety is a public health priority and an essential step to achieving food security. Effective food safety and quality control systems are key not only to safeguarding the health and well-being of people, but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets.

Legislation on the general principles of food law (Regulation (EC) No 178/2002) makes it illegal to place unsafe food on the market. In order to achieve the general objective of a high level of protection of human health and life, a general obligation is placed on food business operators to ensure that all stages of production, processing and distribution of food under their control satisfy the relevant hygiene requirements laid down in Regulation (EC) No 852/2004 and any specific requirements provided for in Regulation (EC) No 853/2004 which lays down specific hygiene rules for food of animal origin. Prevention is the ultimate goal of food control and is only possible if food producers and food businesses are correctly implementing effective programmes of food safety management.

In addition food shall comply with the relevant requirements of food law regarding to the maximum contents of some specific hazards in food. Therefore microbiological criteria give guidance on the acceptability of foodstuffs and their manufacturing processes. (Regulation (EC) No 2073/2005). Food must also comply with maximum limits for contaminants as well as for pesticides, food additives and veterinary drug residues as it is depicted in their respective regulations (Regulation (EC) No 396/2005; Regulation (EC) No 1881/2006; Regulation (EC) No 1333/2008; Regulation (EC) No 37/2010).

According to these criteria, food injurious to health or unfit for human consumption and so considerer to be unsafe, must be deemed. Therefore not complaining with food regulations is contributing to FLW. With that in mind, preventative actions, such as the application of Good Hygiene and Manufacturing Practices (GHP, GMP) and the Hazard Analysis Critical

Control Point (HACCP) principles contribute not only to achieve food safety but also to prevent FLW.

6.| Food preservation strategies

Although it is not possible to completely prevent spoilage of foods, different strategies can be found to delay this process and to minimize its impact. Food preservation may be defined as the processes or techniques undertaken to maintain internal and external factors which may cause food spoilage and contamination. Factors controlling food safety and food spoilage, especially those related to microbial growth, are often the same. Therefore, the following is a summary of the food preservation strategies that allow to delay food quality loses, food spoilage and/or food contamination so that food maintain the desired properties or nature for as long as possible. As food preservation technologies helps to increase the shelf life of food they have an important role in reducing food waste.

Food processing can be classified according to different criteria. The most commonly used preservation methods are summarized, although technological advances are constantly being developed. Around the world, development practitioners in public, private and non-governmental organizations are constantly designing and implementing innovative solutions to address these challenges.

6.1. | Physical processing technologies

Food can be preserved by physical methods like:

• **Drying**

Drying or dehydration is one of the oldest methods of food preservation. It is the process of removing water in food by means of evaporation to reduce water activity, slowing down by this way the growth of germs and the chemical-enzyme action. It also reduces weight and volume of foods, facilitates foods storage, packaging, and transportation, and also provides different flavours and smells (Amit et al., 2017). From ancient times drying of food has been made under the sunlight. However, nowadays there are many types of drying methods to dehydrate foods which may be done with a variety of sophisticated equipments. Food items, such as fruits, vegetables, meats, and fishes, are processed by drying. Instant coffee and tea are also produced by spray drying or freeze drying.

• **Thermal food preservation**

Heat processing of foods is mainly designed to result in a specific reduction in numbers of foodborne pathogens or elimination of food spoilage organisms, thus ensuring microbiological safety and increased shelf life. Thermal inactivation is safe and chemical-free and provides tender, cooked flavours and taste. Heat treatments may also have some drawbacks such as undesirables flavours and texture changes when overcooking or nutrients loos. There are different types of heat treatment and duration of time.

Pasteurization is a physical preservation technique in which food is mild heat treated so that non-spore forming pathogenic bacteria are inactivated. Pasteurization kills most spoilage organisms and deactivates enzymes which increases the shelf life of food.

The efficiency of pasteurization depends on the temperature–time combination which is mostly based on the thermal death-time studies of heat-resisting microorganisms. On the basis of temperature and heat exposure, pasteurization can be categorized as VAT or LTLT (low temperature long time), HTST (high temperature short time) and UHT (ultra-high temperature); the latter being more effective to inactivate thermo-resisting spores. Therefore UHT pasteurized products have a longer shelf life than other pasteurized products, although once the package is opened, then it must be kept inside the refrigerator.

Thermal sterilization at temperatures exceeding 100°C is a heat treatment process that completely destroys all the viable microorganisms resulting in a longer period of shelf life. In reality, viable spores may persist in the product, but they are prevented from growing by other factors such as low pH (pH <4.5), low water activity and preservatives such as nitrite and salt.

• **Freezing**

Freezing changes the physical state of a substance by forming ice from water below freezing temperature. It reduces the amount of liquid water in the food and diminishes water activity (Amit et al, 2017). Freezing inhibits the growth of spoilage and pathogenic microorganisms while both, enzymatic and non enzymatic changes continue at much lower rates. Therefore, during frozen storage there is a slow progressive change in the organoleptic quality of food (Rahman, 2007). In addition microorganisms remain alive tough not active. Therefore, they will easily grow when food is defrosted. In general, slow freezing of food tissues results in the formation of larger ice crystals in the extracellular spaces, while shorter freezing time produces small ice crystals distributed throughout the tissue and therefore cause less damage to cell structure or texture of the food.

• **Chilling**

In chilling process, the temperature of foods is reduced and maintained between −1 and 8 °C to store the food products for a few days or a more prolonged period of time depending upon the food type. The cold temperature reduces the rate of biochemical and microbiological changes extending the shelf life of fresh and processed foods.

6.2. | Biological processing technologies

Fermentation is a typical example of biological preservation of food trough the growth of microorganisms. Fermentation can be spontaneous or induced by addition of known microorganisms. The process generate a number of beneficial products which minimizes food spoilage. Bacteria, yeasts, and

molds are the most common groups of microorganisms involved in fermentation of a wide range of food items, such as dairy products, cereal-based foods, and meat products (Amit et al., 2017). Accordingly there are different techniques such as alcoholic fermentation which results from the yeast action on sugar converting this into alcohol and carbon dioxide; vinegar fermentation that is produced after alcohol fermentation or the lactic acid fermentation due to bacteria. In fact, lactic acid bacteria (LAB) are the main microorganisms used for fermenting food. LAB renders several compounds as organic acids, which are capable to exert antimicrobial properties as well as imparts unique flavour and texture to the food products. Fermentation enhances as well nutritional value, healthfulness, and digestibility of foods.

6.3. | Chemical processing technologies

Food preservation using chemical reagents is a well-known method used since ancient times. Wide varieties of chemicals or additives are used in food preservations both natural and synthetic. At any case, they must be safe to consume under the intended conditions of use and must accomplish some desired function in the food to which they are added.

Organic acids are natural constituents of many foods that are produced or added for preserving them for deterioration. Effectiveness of organic acids as food preservatives depends on many factors such as the type of acid used and its concentration or the product storage temperature and water activity and pH values. As example, acetic acid is used to lower the pH in the water phase of foods, restricting microbial growth; sorbic acid, that naturally occurs in some fruits, and benzoic acid are both effective antimicrobials against yeasts and moulds; many others as for example propionic acid, fumaric, malic, succinic and tartaric acids are frequently used.

Adding salt or sugar to food is a common method of preserving food products. Sugaring is mostly used for the preservation of fruits such as peaches or strawberries with which jam or syrup can be made. Salty is used to preserve food products by dry curing (meat, fish, etc.) or wet curing (vegetables). Both, salt and sugar draw the water out of microorganisms and retard their growth.

In addition, a variety of natural or synthetic chemical substances can be added to enhance food preservation. Food additives are used intentionally during processing, packaging, or storage of foods to bring desired changes in food characteristics. However, there is as a current renewal interest in natural occurring antimicrobial and antioxidant compounds as a response to consumers' requirements for fresher and more natural additive-free food products. Food preservation using chemical reagents is a well-known method used since ancient times. Wide varieties of chemicals or additives are used in food preservations both natural or synthetic. At any case, they must be safe to consume under the intended conditions of use and must accomplish some desired function in the food to which they are added.

6.4. | New preservation techniques

The preservation methodologies explained are those consider traditional and have several advantages since they are economical, safe and well known. However, they also have some drawbacks such as lack of uniformity in treatment and changes that occur in food quality attributes.

Nowadays, there is a consumer's demand of healthy, safe, free of synthetical chemical preservatives and quickly prepared food. For this reason the development of innovative non-thermal food processing technologies resulting in food that is safe from a microbiological point of view, healthy, and better maintaining the properties of the fresh product have received growing attention.

The most important emerging technologies are based on irradiation; pulse electried field (PEF); high hydrostatic pressure or ultra-high pressure processing (HPP) which is the most developed one; new ways of applying heat and/or packaging, in addition to various antimicrobials; and applications of nanotechnology. In addition, combined processes or 'hurdle technologies' are frequently used. It consist of the combination of different preservation technologies, increasing inactivation while reducing the treatment intensity of each process, and thus decreasing food quality losses.

6.5. | Food preservation at home

The greatest amount of FLW in the food supply chains of developing and developed economies, are produced at home. This is why consumer food waste has been identified as a major challenge.

Consumer's responsibility includes proper food handling, storage, and at-home preparation. Doing this is important not only for preserving the quality, nutritional and organoleptic properties of food products, but also to keep food safety. As regards, in addition to all the personal hygiene measures that must be applied to avoid food contamination (frequent washing of hands and working areas, having hair tied back, not sneezing or coughing on food, regular changing of kitchen cloths, storing garbage in containers with lids placed away from food handling areas, etc..) it is important to follow the indications below.

During shopping, products that do not need cold temperatures should be collected first (can, drinks,...); then follow by the refrigerated ones (fruits, vegetables, meats, yogurts,...) and finishing with the frozen food. By purchasing the products needing cold temperature at the end, we will prevent the cold chain from being broken avoiding to reach temperatures that facilitate microorganisms to grow.

Consumers have to choose the products according to their needs. As we have seen before, labelling provide information which may help to do a more logical and coherent purchase within our needs.

Shopping carts must be properly organized. Therefore, food must be separated from toxic products (cleaning products, insecticides, etc.). When bagging, food should be separated while maintaining the same organization as during the selection of products: grouping foods that do not need cold, placing the refrigerated ones together and isolating frozen ones in isothermal bags. In addition, foods that may contaminate others (e.g. raw meats or fish with fruits and vegetables) shouldn't be together. As for, it is advisable not to place raw meat and fish on top of other products, as they could drip and contaminate them.

During transport, foods that need cold for preservation (dairy, meat, fish, etc.) will increase their temperature and this can lead to the multiplication of microorganisms. When buying products that need refrigeration or freezing, the transport home should be carried out as soon as possible, especially in summer. Perishables should be placed in the coolest part of the car during the trip home.

Once at home foods must be rapidly classified according to their temperature requirements. Labelling usually provide information about the most appropriate way for food preservation and they should be carefully read. The packaging of the products shouldn't be thrown away without making sure that the way of conservation and use is completely known.

As regards, it should be highlighted how important food packaging is to prevent food from becoming contaminated and isolated from the environment. Properly designed and manufactured packaging, allow food products to be stable for longer and to maintain their quality characteristics. But if the packaging is damaged, neither their quality nor the safety can be guaranteed. Therefore, it is particularly significant to dwell on the analysis of packaging. Specifically, bumps that can generate pores at the junction points of canned packaging must be avoided and supervised.

Bacteria that may contaminate food are very active at room temperature. Between 5ºC and 65ºC, most potentially pathogenic microorganisms grow rapidly and multiply in a very short time. Despite cold doesn't kill microorganisms, it slow down or stop their development.

Although microorganisms can be partially or totally inactivated with good cooking, until the time comes to cook, food must be kept at an appropriate storage temperature. As rapid growth of microorganisms can occur, foods needing cold for preservation should be quickly stored and never being allowed to remain at room temperature for more than two hours, or even less in the summer time. It is particularly important in certain foods such as poultry meat, minced meats, fish, foods containing raw egg such as sauces and

mayonnaises, unpasteurized milk and dairy products or foods that will not undergo further treatment (cut fruits and vegetables, cooked food....) which should be carefully handled and preserved.

However, cold should be avoided in some foods that do not freeze well. Further information about food storage conditions is summarized below.

Regarding at-home food preparation, we should first be attended to the food labelling instructions related to “mode of preparation”. Besides that, marinating food should be done in the refrigerator so to avoid bacteria growing rapidly at room temperature. Marinade liquid never should be used later as sauces, unless they boil quickly first. Cooking process should ensure that food reaches 70 °C in all its parts.

Once cooked, foods that are not going to be immediately eaten must be kept cold. Putting hot food in the refrigerator can negatively affect the temperature of others. Therefore, cooked foods should be cool before putting them in the freezer or in the refrigerator. When reheating a previously cooked food that has been refrigerated or thawed, we must ensure that all parts of the food, including the centre of it, reach at least a temperature of 70 ºC, for at least 15 seconds.

Finally, to prevent food waste and save money it is important to fully understand the terms “Best Before” and “Use By” dates on food packaging. As it has been explained before, any food after expiration of the “use by” date must be uses. However, “Best before” dates appear on a wide range of refrigerated, frozen, dried (pasta, rice), tinned and other foods (vegetable oil, chocolate, etc.). In those cases it is recommended to check if the packaging is intact, and if the food looks, smells and tastes good before throwing away food past its “best before” date. Once a food with a “best before ”date on it has been opened, follow any instructions such as “eat within three days of opening”, when applicable.

6.5.1. Food storage. FIFO and FEFO systems

Non refrigerated foods

Foods that do not need to be refrigerated must be kept in a dry, cool and dark place. In particular, it is not recommended to keep cold some fruits and vegetables and consumers should be awareness about how to store them to stay fresh longer inside or outside the refrigerator. Many fruits give off natural gases as they ripen, making others to spoil faster. Store bananas, apples, and tomatoes by themselves. Also outside the fridge is recommended to keep citrus (limes, lemons, oranges, mandarins, grapefruits), whole melon, watermelon, pineapple and pomegranate. Low temperatures shouldn’t be used as well for exotic fruits and fruits needing ripen. Vegetables no needing cold include cucumbers, beets, peppers, garlic, onion, potatoes, sweet potatoes, pumpkin or ginger.

Though there are some fruits that may ripen at room temperature, afterwards it is recommended to keep them cold. Some examples are avocados, kiwis, nectarines, peaches, pears or plums.

If any canned product is opened and not consumed in its entirely, the original container should be removed and transferred to an airtight container for storage in the refrigerator.

Refrigerated foods

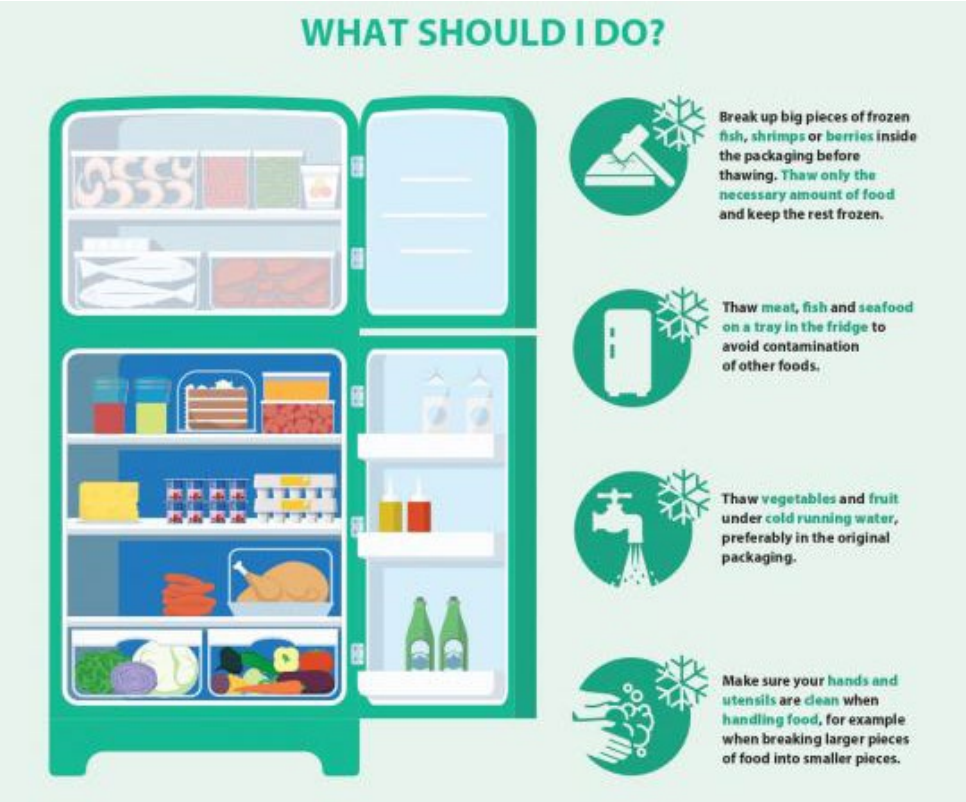
Some of the bacteria that cause food poisoning can multiply at room temperature in a very short time, and one of the best ways to avoid this is to refrigerate food at the right temperature.

The ideal cooling temperature must range between 0 and 5 °C. A thermometer to control the temperature of the refrigerator and freezer, can be a good tool to adjust the cooling power in relation to the load. Leave the door open for the shortest possible time. The capacity of the refrigerator must be appropriate to the number of people it must serve.

Not only temperature is important but also how food products are distributed may affect their shelf-life. The refrigerator should not be overloaded and leave air space around the containers or packages. This allows cold air to circulate and helps to ensure rapid cooling. To prevent some foods from contaminating others, raw food should be always separated from processed or cooked food. For this reason, packaging and lids must be simultaneously used. Freezer wrap and freezer-quality plastic bags may also help to reduce dehydration and quality loss.

It is also important to place the food in the fridge according to their preservation needs:

- On the top shelf: cooked food (packaged food leftovers, container with canned goods not used in their entirety, etc.).
- On the centre shelf: eggs, dairy products and sausages
- On the bottom shelf: raw foods: meat, poultry and fish always packaged and separated properly, and products thawed, so we will avoid the exudate that gives off falling on top of other foods.
- At the door: drinks or foods with frequent consumption, such as milk, soft drinks or juices.
- In the greenish: Fruits and vegetables needing cold. They should be placed in different bins. It is recommended not to wash berries until eating them in order to prevent mold.



https://www.efsa.europa.eu/en/infographics/defrosting-food-safely

Frozen food

Freezing food is a very common preservation methodology recommended, among others, to keep foods that will not be consumed in the coming days, such as fish or meat no matter weather they are raw or cooked as well as vegetables previously scalded or cooked. However, freezing is not suitable for some products such as those made of rice, potatoes or pasta since their texture is modified in an undesirable way. Neither it is recommended for vegetables that are eaten raw (lettuce, tomatoes,….), nor for whole fruits unless they be used afterwards to make smoothies or similar products. Foods with a high fat content, such as cream and some sauces, tend to be cut when frozen. Dairy products also do not withstand freezing well.

Freezing should be done very quickly and at low temperatures. The lower the temperature is, smaller ice crystals will be created and that will affect food texture to a lesser extent.

It is advisable packaging food products in small portions. This not only facilitates their freezing, but also allows a better organization of the rations. Airtight plastic bags for freezing are very useful for packaging. They should be used only once and as much air as possible should be removed. On the other hand, it must be taken into account that when food is frozen it expands, so it will be necessary to leave a proportional space to prevent the containers from bursting.

The duration of the food in the freezer will be determined by the stars of the domestic freezing apparatus:

- 1 star: -6 °C minimum temperature, so they will be freezers to keep a few hours the food.
- 2 stars: -12 °C minimum temperature. Food can be frozen for up to about three days.
- 3 stars: -18 °C minimum temperature. Food lasts for months frozen.
- 4 stars: -24 °C freezing is faster and allows you to freeze more food and for longer.

Also depending on their nature, food products can be kept in the freezer for longer. It is recommend not to exceed a storage period of two months for minced meat; three months for bread, prepared or cooked food, fatty fish and seafood; six months for pork and lean fish; ten months in the case of vegetables and chicken and game meat. Freezer should be at -18ºC and food must not be refreeze, because successive freezes detract from the quality of food and make it easier to contamination.

Finally it is advisable to clean frequently the inside of the refrigerator and whenever spills or drips occur. Additionally, pantries, fridges and freezers should be periodically cleaned and revised. The maxim must be adhered to: **"First in, First out"** or **"first in is first out"**. In this way, we will first consume those products with a closer expiration date. Not to leave forgotten foods at the bottom of the freezer it is recommended to mark the freezing dates with a marker. In the fridge it is recommended putting the foods we just have bought behind the ones already inside.

7.| Food safety in the redistribution of food

Food donation or food redistribution is part of the strategy to reduce food waste. The primary focus of food waste prevention should be to act at the source by limiting the generation of surplus food at each stage in the food supply chain, but when food surpluses occur, the best destination is to redistribute them for human consumption, which ensures the highest value use of edible food resources (European Commission, 2017; Agencia Catalana de Seguridad Alimentaria, 2019).

Surplus food may arise for a variety of reasons: foods which do not meet manufacturer and/or customer specifications (e.g. variations in product color, size, shape, etc.); difficulties in managing supply and demand that lead to over-ordering and/or cancelled orders; or issues relating to date marking may also prevent foods from being sold and distributed through the usual retail channels.

Food business operators may donate surplus food through redistribution organizations (such as food banks), gleaning networks and other charity organizations or directly to consumers. In all cases, surplus food shall be redistributed with the guarantee that is fit for human consumption and compliant with all food safety requirements. In this sense, foods suitable for food donation may include, for instance, products which are time-marked and have passed the “best before” date but can still safely be consumed; have been collected and/or confiscated by regulatory authorities for reasons other than food safety, etc. (FAO, 2015; European Commission, 2017).

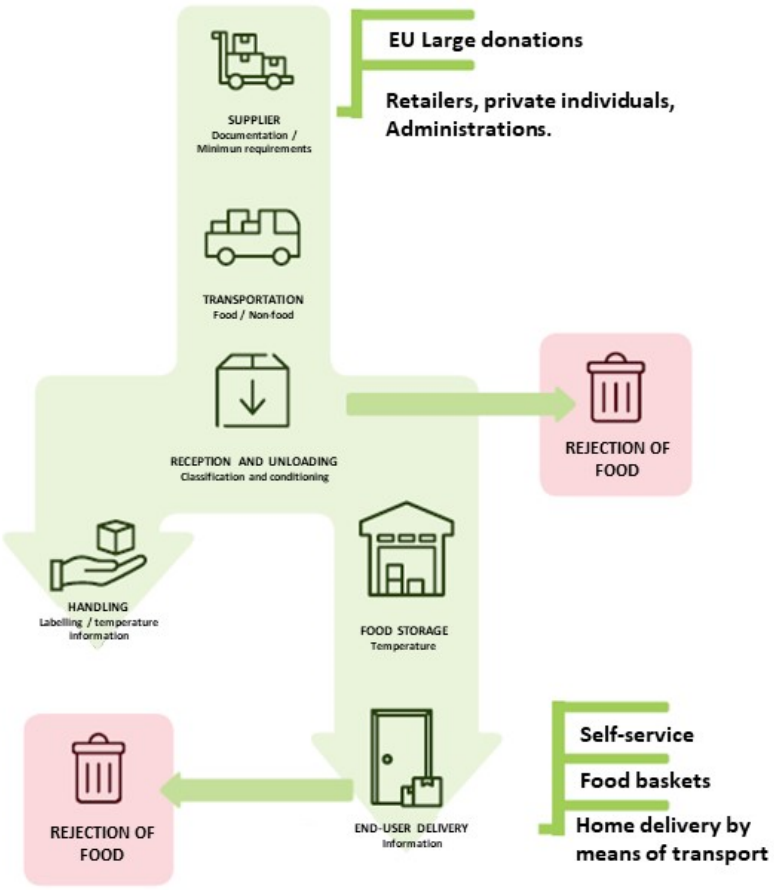


Figure 8. Flow chart of food donation activities (Agencia Catalana de Seguridad Alimentaria, 2019). Translation: ZERO_WASTE project

Food business operators may redistribute food for the purpose of food donation subject to the following conditions (Regulation (EU) 2021/382):

- They shall routinely check if food under their responsibility is not injurious to health and is fit for human consumption by taking into account at least:
  - the date of minimum durability or the “use by” date, ensuring sufficient remaining shelf-life left to allow for the safe redistribution and use by the final consumer.
  - the integrity of the packaging.
  - the proper storage and transport conditions, including applicable temperature requirements.
  - the date of freezing (when applicable).
  - the organoleptic conditions.
  - the assurance of traceability.

- If the check carried out is satisfactory, they may redistribute food in accordance with the following:
    - for food for which a “use by” date is applied, before the expiry of that date.
    - for food for which a date of minimum durability (“best before”) is applied, up to and after that date.
    - for food for which a date of minimum durability is not required, at any time provided.

The activities around the redistribution of surplus food does not change or replace the normal legal requirements that apply to the provision of food. Volunteers handling food, the social organization's facilities and food products shall satisfy the general hygiene requirements laid down in Regulation (EC) No 852/2004, as well as requisites of traceability, among others (Agencia Catalana de Seguridad Alimentaria, 2019).

Requisites for food handlers

- Volunteers shall maintain a high degree of personal cleanliness.
- No person suffering from a disease likely to be transmitted through food is to be permitted to handle food.
- They must wash and dry their hands thoroughly before handling food, and wash and dry them again frequently during work.
- Not smoke, chew gum, spit, or eat in a food handling or food storage area. Never cough or sneeze over food.
- They must cover all cuts and wounds with a wound strip or bandage.
- Disposable gloves need to be changed regularly.

Establishment and facilities requisites

- Design and layout of food establishments should permit good food hygiene practices, including protection against cross-contamination between and during operations with foodstuffs.
- Structures should be soundly built of durable materials and be easy to maintain, clean and where appropriate, able to be disinfected.
- Depending on the nature of the food operations undertaken, adequate facilities should be available for heating, cooling, cooking, refrigerating and freezing food, for storing refrigerated or frozen foods, monitoring food temperatures, and when necessary, controlling ambient temperatures to ensure the safety and suitability of food.

Requirements for foodstuffs

- When surplus food is redistributed, end beneficiaries must have access to the same information that is required and provided when food is purchased in store. The minimum essential information on the label must be the following: identification of the food product identification; identification of food business operator; minimum durability date (“best

before") or "use by" date; the list of ingredients, including allergen information; and storage conditions.

- Food products shall not evidence signs of spoilage.
- Foods need to be stored at adequate temperatures:
    - ≤ -18 ºC Frozen foods
    - ≤ 4 ºC Poultry meat, fish and refrigerated meals with a shelf life of more than 24 hours
    - ≤ 7 ºC Fresh pork, veal and lamb
    - ≤ 8 ºC Refrigerated meals with a shelf life of less than 24 hours
    - ≥ 65 ºC Hot meals
- Unpackaged food must be protected with packaging that insulates it from outside contamination.

To know more

(1) Food composition

Proteins

Proteins are polymers of amino acids linked via α-peptide bonds. When consumed, proteins are digested in the gastrointestinal tract, absorbed as small peptides and free amino acids, and then used for the resynthesis of proteins in cells. Nine amino acids are considered nutritionally indispensable or essential in humans because the body is not able to synthesize them: leucine, valine, isoleucine, histidine, lysine, methionine, threonine, tryptophan, and phenylalanine (Watford and Wu, 2018).

Meat, seafood, eggs, and milk are all considered excellent sources of high-quality protein. Some plant-based foods, most notably legumes such as beans, peas, and lentils, but also nuts, seed and soy products do contain substantial amounts of this macronutrient (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Watford and Wu, 2018).

Lipids

Lipids comprise a group of polar and nonpolar compounds, that includes triglycerides, diglycerides, monoglycerides, fatty acids, phospholipids, and sterols (such as cholesterol). Lipids have many roles in the organism including a source of readily available and stored energy, a structural and functional component of all cell membranes in addition to helping with the absorption of fat-soluble vitamins and other food components (Field and Robinson, 2019).

Triglycerides comprise 90–95% of the lipids in the diet and body. A triglyceride is composed by three fatty acids linked to a glycerol molecule. The three types of fatty acids that compose triglycerides are saturated, monounsaturated and polyunsaturated fatty acids (e.g. omega-3 and omega-6). The ingestion of saturated fats must be avoided because they are the main reason of high LDL cholesterol (or bad cholesterol) levels in the organism. This type of fats are found in many animal products such as butter, cheese, whole milk, ice cream, cream and fatty meats as well as in some vegetable oils such as palm and coconut oils. Eating unsaturated fats can help lower blood cholesterol. Foods with high levels of monounsaturated fats include vegetable oils such as olive oil, canola oil, peanut oil and sesame oil, avocados, and a variety of nuts and seeds. Foods that contain polyunsaturated fats include many vegetables oils and fatty fish such as salmon, mackerel, herring and tuna.

Carbohydrates

Carbohydrates are the body's main source of energy, and are subdivided into the following categories on the basis of the number of sugar units and how are chemically bonded to each other: sugars, starches, and fibres.

Sugars are intrinsic in diverse foods such as fruits and milk products, but also are added to sweeten foods and beverages to improve their palatability.

Many sugar-added food products provide calories but insignificant amounts of vitamins, minerals or other essential nutrients. Complex carbohydrates, called polysaccharides, include starches and fibre. Starches are found in many foods, including vegetables, legumes, and grains. They are broken down during digestion to form sugars that provide energy. Fibre, that is present in all plant foods, unlike most starches, cannot be broken down by digestive enzymes and pass relatively intact into the large intestine.

Vegetables, fruits, whole grains, milk, and milk products are the major food sources of carbohydrates (Slavin and Carlson, 2014).

Vitamins and minerals

Vitamins are organic dietary constituents that are divided into two categories: water soluble, which means the body expels what it does not absorb, and fat soluble where leftover amounts are stored in the liver and fat tissues as reserves. The water-soluble vitamins are the eight B vitamins (B-1 or Thiamin, B-2 or Riboflavin, B-3 or Niacin, B-5 or Pantothenic acid, B-6 or Pyridoxine, B-7 or Biotin, B-9 or Folic acid, and B-12 or Cyanocobalamin) and vitamin C. The fat-soluble vitamins are A, D, E, and K (Costa-Pinto and Gantner, 2020).

Minerals are inorganic substances that are divided into major minerals (macro-minerals) and trace minerals (micro-minerals). Major minerals are calcium, magnesium, potassium, sodium, chloride, phosphorus and sulphur, while trace minerals are iodine, zinc, selenium, iron, manganese, copper, cobalt, molybdenum, fluoride and chromium (Gharibzahedi and Jafari, 2017).

A broad healthy diet ensures to get a variety of vitamins and minerals, and in the proper amounts. This involves an emphasis on fruits and vegetables, whole grains, beans and legumes, low-fat protein, and dairy products.

(2) Factors affecting food spoilage

Intrinsic factors

Food structure and composition

In general, microorganism can easily grow in fluid and semi-solid foods that rapidly spoil as compared to solid foods than tend to spoil from their outside surfaces inwards, these being the first surfaces to become contaminated (Petruzzi et al., 2017).

Additionally, most solid and semi-solid foods (sausages, margarine, etc.) do not have a homogeneous and uniform structure. Therefore, the physical and chemical factors influencing microbial growth and also chemical and

biochemical reactions, can vary according to the location in the food (Man, 2004).

As for food composition, many examples of how it influences food spoilage can be cited. As examples, a high content of acetic acid in pickled food and non pasteurized sauces provides stability and prevents from microbial growth whereas the fat content of butter and margarine also prevents microbial spoilage.

Apart from that, different agents either naturally present in foods or formed or added during processing, have been assessed for their efficacy against chemical reactions and microorganisms conducting to food spoilage. Some examples of chemical agents commonly used in the food industry are organic acids, sodium or potassium salts. Plant extracts as clove, mint, oregano, rosemary, and thyme as well as spices have demonstrated to have antimicrobial and antioxidant properties (Burt, 2004; Tajkarimi et al., 2010).

Water activity

The lowest aw at which the vast majority of food spoilage bacteria will grow is about 0.90. Yeasts and molds can grow in foods with lower water activity, above 0.85 and 0.80 respectively, with the lower limit for growth of osmotolerant species of 0.60 (ICMSF, 2002).

pH (hydrogen ion concentration, relative acidity or alkalinity)

The pH range of a microorganism is defined by a minimum value (at the acidic end of the scale) and a maximum value (at the basic end of the scale) at which it may grow. The optimum growth pH is the most favourable pH value for the growth of a microorganism. Moving away from this value in either direction slows microbial growth. Acidification of food may be carried out by direct addition of organic and other appropriate acids but also by fermentation process as in yoghurt manufacturing.

It is important to take into account that food may start with a pH value that precludes bacterial growth, but as a result of the metabolism of other microbes (yeasts or molds), pH shifts may occur and permit bacterial growth (FDA, 2012).

Redox potential

Redox potential generally represents how easily a substrate loses or gains electrons. Oxidation involves the loss of electrons; an element or compound losing electrons oxidizes. Oxidation also occurs when an element or compound reacts with oxygen. Therefore, the availability of oxygen affects the oxidation-reduction (redox) (Eh) in a food product.

Despite of aerobic and anaerobic microorganism, there are others capable of aerobic respiration in the presence of oxygen or fermentation in the absence of oxygen. They are facultative anaerobe. In addition,

microaerophilic microorganism require low concentrations of oxygen for growth.

Extrinsic parameters

Temperature

Values for microbial growth, have a minimum and maximum range with an optimum temperature for maximal growth. The optimum growth temperature determines its classification as a thermophile, mesophile, or psychrophile. The rate of growth at extremes of temperature determines the classification of an organism (e.g., psychrotroph, thermotroph) (FDA, 2012).

(3) Food spoilage mechanisms

Physical spoilage

Moisture transfer can cause changes in **glass transition temperature (Tg)** a property that reflects the level of molecular mobility in food. It significantly affects the stability and shelf life of food products. In terms of molecular structure, there are three forms of powders: crystalline, amorphous, and the mixture of the two. The amorphous matrix may exist either as a very viscous glass or as a more liquid-like rubber. Tg is the temperature range where food polymers undergo a phase change from rigid/glassy to rubbery or soft. Many low-moisture foods, including sugar-based products such as hard candy, dried products as milk and whey powder, starch-based products like bread or crackers and frozen foods are in the amorphous metastable state. These foods can be in an amorphous glassy state or an amorphous rubbery state, depending on temperature and moisture content. Increase in temperature can cause transition of a food from a glassy to a rubbery state. Changes in water content also affect this parameter. As example, dry food products such as crackers are expected to be crisp. However, it they are stored in a high humidity environment, they will absorb water (lowering Tg) and undergo glass transition to become tough and soggy. Conversely, soft bakery products are expected to be moist and chewy; however, these products tend to lose moisture (raise Tg) to the point where they undergo glass transition and become glassy, hard and brittle (Kong and Singh, 2016; Singh and Anderson, 2016; Amit et al., 2017). Another effect of glass transition is caking of dry powders when gaining moisture.

Crystallisation

This process consists of two main successive stages; nucleation and crystal growth. The interaction between these two steps determines the crystal characteristics. In many products, the goal of crystallization is to generate a certain texture or appearance that makes the product acceptable. Thus, nucleating many crystals that remain small within the product itself is often the goal. The crystals also must have the proper shape and/or polymorph to enhance stability of the product during storage and distribution (Hartel, 2002). However, crystallization is undesired in others. This is the case of foods with a high sugar content that can undergo sugar crystallization either

by moisture accumulation or by increasing temperature. As a consequence, sugar comes to the surface from inside, and a grey or white appearance is noticed (Amit et al., 2017). Additionally changes in the crystal structure in terms of shape, size and crystal size distribution may result in undesired texture and sensory properties of food. Therefore, large ice crystal growth during freezing process can also contribute to food degradation. Different techniques may be used to prevent crystallization or to avoid changes in crystalline structures that may occur during freezing and storage.

Chemical spoilage

Oxidation

Lipid oxidation is one of the most common spoilage reactions in oils and foods containing fats such as nuts, fried foods, meats or milk powder resulting in non desirable rancid odours and flavourings. The **oxidative rancidity** is a free radical chain reaction that involves abstraction of a hydrogen from the fatty acid chain followed by a series of reaction with oxygen, rearrangements, and chain cleavage. Fat is oxidized and decomposes into compounds with shorter carbon chains such as fatty acids, aldehydes, and ketones all of which are volatile and contribute to the unpleasant smelling compounds. Oxidative rancidity leads also to the formation of toxic compounds

Because of the 'spontaneous' nature of the reaction the process is frequently referred to as autoxidation. Rancidification can be catalysed by the presence of metal oxides and exposure to light increases the reaction rate.

Oxidation also affects other food components such as pigments, leading to changes in colour, as is the case of fresh meat by the oxidation of oxymyoglobin and myoglobin to produce metamyoglobin. The sensitivity to oxygen of some vitamins, such as vitamins C (L-ascorbic acid) and B1 (thiamine) or the fat-soluble A and E vitamins, can lead to a decrease in the nutritional food value.

Hydrolysis

Hydrolytic rancidity causes lipid degradation by the action of lipolytic enzyme lipases catalysing lipolysis. This reaction implies the cleaving of free fatty acids from triglyceride molecules in the presence of water. These free fatty acids have rancid flavours or odour. The released volatile free fatty acids have shorter chain lengths, and sometimes stiff mal odour and taste.

Hydrolytic rancidity mainly affects products containing lauric oils such as palm and coconut oils. The fatty acids released include capric, lauric and myristic acids, which have a differential soap aroma. For this reason it may also called soap rancidity. Lipases are also found in cereals and milling products that may also suffer from this spoilage process.

Non-enzymatic browning

Non-enzymatic browning, is an extremely complex process and is the reaction between reducing sugars and proteins by the impact of heat. The Maillard reaction also takes place at room temperature but at a much slower rate and occurs at its slowest by low temperatures, low pH, and low aw levels.

Colour darkening, reducing proteins solubility, developing bitter flavours, and reducing nutritional availability of certain amino acids are the common outcomes of Maillard reaction. It is also responsible for the development of harmful compounds.

Microbial food spoilage

Bacteria

Bacteria related to food spoilage are divided for convenience into broad categories (Huis in't Veld, 1996):

- Gram-negative rod shaped bacteria: Most raw or fresh foods are typically spoiled by the growth of Pseudomonas spp., during aerobic storage producing slime and odours as the main signs of spoilage. Aeromonas, Photobacterium, Shewanella and Vibrio may also grow rapidly at chill temperatures and spoil foods. At a temperature above 5- 10°C enterobacteriaceae generally dominate over Pseudomonas spp. and become responsible for spoilage.

- Gram-positive spore forming bacteria, capable of surviving the pasteurization process may be significant in food spoilage. This includes aerobic Bacillus spp. Best recognised B. cereus may grow at low temperatures (5 °C or less) and produce enzymes which result in 'sweet curdling' and 'bitty cream' in milk. Clostridium spp. do not usually grow at refrigerator temperatures (i.e. 5°C or less), but at slightly higher temperatures may produce gas resulting in 'late blowing' of hard cheeses during maturation.

- Lactic acid bacteria (LAB), encompassing Lactococcus, Lactobacillus, Leuconostoc, Weissella, and Carnobacteria species, are frequently associated with spoilage. Undesirable changes caused by LAB include greening of meat and gas formation in cheeses (blowing), pickles (bloater damage), and canned or packaged meat and vegetables (Petruzzi et al., 2012)

- Other Gram-positive bacteria. Brochotrix thermosphacta may be occasionally present on fresh meats. The increased use of modified atmosphere packaging and vacuum packaging will often allow this microorganism to dominate the microflora. Micrococcus spp are able to grow in the presence of salt and may be responsible for the spoilage of

cured meat products such as bacon producing slime, souring or pigmented growth. These microorganisms also often predominate in freshly collected milk.

Fungi

Fungi frequently linked to spoilage of foods and beverages, and mainly fruits and fruit-based products, include Aspergillus, Mucor, Penicillium, and Rhizopus species. With reference to yeasts, in view of the wide diversity of taxa and the frequently ambiguous character of yeast taxonomy, correct identification of species is often a challenge. Nevertheless, the yeast species that have primarily been associated with spoilage of products such as soft drinks, syrups, dips, salad dressings, and olives, are members of the genera Candida, Lachancea, Saccharomyces, Torulaspora, and Zygosaccharomyces. Yeasts may also contribute to the spoilage of foods of animal origin such as meat and dairy products, albeit to a much lesser extent compared to bacteria (Lianou et al., 2016).

(4) Food hazards

Biological hazards

According to WHO (2020), the major foodborne diseases causes are named bellow:

- Bacteria: *Salmonella*, *Campylobacter*, and *Enterohaemorrhagic Escherichia coli* are among the most common foodborne pathogens that affect millions of people annually, sometimes with severe and fatal outcomes. In particular, campylobacteriosis has been the most commonly reported zoonosis in the European Union since 2005, representing 50% of all the reported cases whereas *Salmonella* remained the most detected agent in the foodborne outbreaks reported (EFSA and ECDC, 2021). Raw milk, raw or undercooked poultry and drinking water are the foods mainly involve in foodborne cases with *Campylobacter*. Examples of foods involved in outbreaks of salmonellosis are eggs, poultry and other products of animal origin.

- Disease occurrence from *Listeria monocytogenes* is relatively low though it may have severe and sometimes fatal health consequences, particularly among infants, children and the elderly. This microorganism can grow at refrigeration temperatures and it is found in unpasteurised dairy products and various ready-to-eat foods.

- Most common viruses infections are caused by norovirus or hepatitis A virus often being food handlers the source of food contamination.

- Parasites such as *Anisakis* spp. are only transmitted through food while others as *Taenia solium*, may also infect people through direct contact with animals. *Cryptosporidium*, *Entamoeba histolytica* or *Giardia*, enter the food chain via water or soil and can contaminate fresh produce.

Evaluation section

1. | Multiple choice questions

1. Food quality assurance along the food chain rely on:
a) primary production stage
b) food industry
c) consumers
d) all statements are true

2. Say what is true regarding food chains nowadays.
a) have been simplified thanks to technology
b) due to globalization are all the same worldwide
c) decisions made at any stage have implications for others
d) don't rely on primary production stage

3. Say what is true with regards to perishability of food:
a) deterioration of food is mainly dependent on food factors
b) sugar and flour are examples of perishable food
c) perishable products usually have a high water content
d) semiperishable food products may be preserved up to several days

4. Choose the false statement related with nutrition and food composition:
a) Nutrients are classified into macronutrients (proteins, lipids and carbohydrates) and micronutrients (vitamins and minerals)
b) Eating saturated fats can help lower blood cholesterol
c) Declaration of saturated fats is mandatory in the nutritional food label
d) Processes that expose foods to high levels of heat cause a great nutrient loss

5. Say what is true regarding to food spoilage:
a) it always represents a risk for human health
b) food composition is a key parameter in relation to food spoilage
c) physical injury is possibly the most important cause of loss in meat and fish
d) bacterial spoilage of butter is of concern

6. Say what is true regarding chemical spoilage:
a) exposure to light increases lipids rancidity
b) enzymatic browning of apples is known as Maillard reaction
c) lowering sweetness in carbonated drinks with aspartame is due to oxidation processes
d) maillard reaction is an undesirable reaction in cooked meat

7. Say what is true regarding microorganisms:
a) they grow easier in solid foods compared to fluids

b) acidification enhance microbial growth
c) growing of microorganisms is not possible at low concentrations of oxygen
d) yeasts and molds can grow in foods with lower water activity than bacteria do

8. Regarding food spoilage say what is not true:
a) enzymatic browning take place in heat treated food
b) moisture exchange is as well a frequent cause of changes in texture of food
c) chilling injury generally occurs at temperatures of 5-15 ºC
d) hydrolytic rancidity is also called soap rancidity

9. Say what is not true. The rate of microorganism grow in food depends on:
a) pH value
b) temperature
c) food composition
d) lipid oxidation

10. Say what is true about food safety hazards
a) processing technologies are used to destroy chemical hazards in food
b) contaminants are hazards not intentionally added to food
c) disease occurrence from Listeria monocytogenes is high
d) chemical hazards are responsible for most of foodborne illness outbreaks

11. Regarding food labelling, indicate the false statement:
a) The indication of the lot to which a foodstuff belongs facilitates traceability
b) Allergens shall be emphasised on the food label
c) It is important to observe in the food label the storage conditions and/or time limit for consumption once the package is opened
d) “Best before” and “Use by” dates mean the same

12. Regarding food processing technologies, say what is true:
a) UHT pasteurized products have a longer shelf life than other pasteurized products
b) freezing kill microorganisms
c) factors controlling food safety greatly differ from those controlling food spoilage
d) adding salt or sugar to food is a common method of biological preservation of food products

13. Which of the following is the correct statement regarding “Best before” date:
a) It refers to quality rather than safety. The food will be safe to eat after this date but may not be at its best
b) The food will not be safe to eat after this date

c) It is appropriate for foods which, from a microbiological point of view, are highly perishable
d) It will be marked on food that goes off quickly, such as ready-to-eat salads

14. What temperature should your fridge be at?
a) 0-5 °C
b) -2- 2 °C
c) -2-8 °C
d) 5-10 °C

15. What temperature should your freezer be at least?
a) -6 °C
b) -12 °C
c) -18 °C
d) 25 °C

16. Choose the correct statement:
a) Shelf-life studies are only focused on microbiological analysis of foods
b) The nutritional declaration Nutri-Score is mandatory in all food labels
c) Food donation or food redistribution is part of the strategy to reduce food waste
d) Foods suitable for food donation may include those products that have passed the “used by” date

17. The “Use by” date…
a) It should be applied on foods which are highly perishable
b) After the ‘use by’ date a food shall be deemed to be unsafe and must not be eaten
c) It shall be followed by a description of the storage conditions of the food product which must always be observed
d) All statements are true

18. Which of the following definitions is wrong:
a) Open life is the period of time during which a food will remain safe and suitable for consumption from its production until packaging
b) Nutrient reference values (NRVs) are a set of values used in nutrition labelling derived from authoritative recommendations for daily nutrient intake
c) Lot means a batch of sales units of a foodstuff produced, manufactured or packaged under practically the same conditions
d) Traceability means the ability to trace and follow a food, feed, food-producing animal or substance intended to be incorporated into a food or feed, through all stages of production, processing and distribution

19. Which is the proper temperature for the redistribution of hot meals?
a) At least 40 ºC
b) 20 ºC

c) < 4 ºC
d) ≥ 65 ºC

20. The “Use by” date is appropriate in the labelling of:
a) Canned fish
b) Minced meat
c) Breakfast cereals
d) Dry-cured ham

2. | Activities/optional exercises

- Choose five food labels and justify the meaning of the "Best before" or "Used by" date marked. Indicate which information appear in each food label that will help the consumer to prevent food waste.

3. | Multiple choice answers

1	d	**6**	a	**11**	d	**16**	c
2	c	**7**	d	**12**	a	**17**	d
3	c	**8**	a	**13**	a	**18**	a
4	b	**9**	d	**14**	a	**19**	d
5	b	**10**	c	**15**	c	**20**	b

Key concepts and vocabulary

Customary name means a name which is accepted as the name of the food by consumers in the Member State in which that food is sold, without that name needing further explanation.

Date of minimum durability of a food means the date until which the food retains its specific properties when properly stored;

Descriptive name means a name providing a description of the food, and if necessary of its use, which is sufficiently clear to enable consumers to know its true nature and distinguish it from other products with which it might be confused.

Food includes drink, chewing gum and any substance, including water, intentionally incorporated into the food during its manufacture, preparation or treatment. It includes water after the point of compliance as defined in Directive 98/83/EC. 'Food' shall not include: (a) feed; (b) live animals unless they are prepared for placing on the market for human consumption; (c) plants prior to harvesting; (d) medicinal products (2); (e) cosmetics; (f) tobacco and tobacco products; (g) narcotic or psychotropic substances; (h) residues and contaminants (Regulation (EC) No 178/2002).

Food business means any undertaking, whether for profit or not and whether public or private, carrying out any of the activities related to any stage of production, processing and distribution of food.

Food business operator means the natural or legal persons responsible for ensuring that the requirements of food law are met within the food business under their control.

Food information means information concerning a food and made available to the final consumer by means of a label, other accompanying material, or any other means including modern technology tools or verbal communication.

Food redistribution is a process whereby surplus food that might otherwise be wasted is recovered, collected and provided to people, in particular to those in need.

Labelling means any words, particulars, trade marks, brand name, pictorial matter or symbol relating to a food and placed on any packaging, document, notice, label, ring or collar accompanying or referring to such food.

Legal name means the name of a food prescribed in the Union provisions applicable to it or, in the absence of such Union provisions, the name provided for in the laws, regulations and administrative provisions applicable

in the Member State in which the food is sold to the final consumer or to mass caterers.

Lot means a batch of sales units of a foodstuff produced, manufactured or packaged under practically the same conditions.

Microbiological criterion means a criterion defining the acceptability of a product, a batch of foodstuffs or a process, based on the absence, presence or number of microorganisms, and/or on the quantity of their toxins/metabolites, per unit(s) of mass, volume, area or batch.

Microorganisms are microscopic organisms as bacteria, viruses, yeasts, moulds, algae, parasitic protozoa or microscopic parasites.
Nutrient loss refers to the nutrient content embedded within food losse and food waste.

Nutrient reference values (NRVs) are a set of values used in nutrition labelling derived from authoritative recommendations for daily nutrient intake. These recommendations are based on best available scientific knowledge of the daily amount of energy or nutrient needed for good health.

Open life is the period of time during which a food will remain safe and/or of a suitable quality for consumption after the primary product packaging has been opened and it is stored as instructed.

Prepacked food means any single item for presentation as such to the final consumer and to mass caterers, consisting of a food and the packaging into which it was put before being offered for sale, whether such packaging encloses the food completely or only partially, but in any event in such a way that the contents cannot be altered without opening or changing the packaging; 'prepacked food' does not cover foods packed on the sales premises at the consumer's request or prepacked for direct sale.

Principal field of vision means the field of vision of a package which is most likely to be seen at first glance by the consumer at the time of purchase and that enables the consumer to immediately identify a product in terms of its character or nature and, if applicable, its brand name. If a package has several identical principal fields of vision, the principal field of vision is the one chosen by the food business operator.

Ready-to-eat food (RTE) means food intended by the producer or the manufacturer for direct human consumption without the need for cooking or other processing effective to eliminate or reduce to an acceptable level microorganisms of concern.

Shelf-life is the period in which a food remains safe to consume and/or retains its quality in reasonable foreseeable distribution, storage and usage conditions.

Traceability means the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.

Useful resources

Useful resources

https://www.eufic.org/en/healthy-living/article/understanding-nutrition-information-infographic

https://ec.europa.eu/food/system/files/2016-10/labelling_legislation_infographic_food_labelling_rules_2014_en.pdf

https://ec.europa.eu/food/safety/labelling_nutrition/labelling_legislation_en/food_labelling_information_system/start/select-countries

http://www.fao.org/3/Y4358E/y4358e00.htm

https://www.who.int/publications/i/item/9789241594639

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