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Course handout entitled

Legislation

Courses for first-year Master's students in Cereal and Derived Products Technology

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APHA: American Public Health Association

NACMCF: National Advisory Committee on Microbiological Criteria for Foods

CAC: Codex Alimentarius Commission

ILSI: International Life Science Institute

HACCP: Hazard analysis and critical control point

GHP: Good hygiene practice

GMP: Good manufacturing practice

BABBMA: Bangladesh Auto Biscuit and Bread

Manufacturers' Association

CCP: Critical control point

PRPs: Prerequisites programs

oPRPs: Operational prerequisites programs

BDS: Bangladesh standards

CL: Critical limit

HA: Hazard analysis

HRM: Human resource management

RI: Risk index

CoA: Certificate of assurance

QA: Quality assurance

FIFO: First in first out

SOP: Standard operating procedure

MC: Moisture content

aw: Water activity

PLC: Programmable logic control.

Introduction

Introduction

Food legislation is a constantly evolving field that covers a wide range of topics, from regulations on ingredients to labeling standards and food safety rules. Food safety has become a constant concern all over the world, leading healthcare institutions and governments of several countries to find ways to monitor production chains. In this context, it is essential that quality management tools be adopted. These tools should emphasize the standardization of products and process, product traceability, and food-safety assurance. The basis of the food-safety system to be adopted in the food industry consists of a combination of good manufacturing practices (GMP), sanitation standard operating procedures (SSOP), and a hazard analysis and critical control point (HACCP) system (**de Oliveira et al., 2016**).

The HACCP system has been known as the food safety system of choice, and this voluntary solution has been adopted by Europe and North America at industry level. In addition, HACCP is a science-based framework that allows for the development and management of a continuous, cost effective food safety policy. It also helps food producers to create a higher standard of food safety that could not be accomplished by merely adopting simple public hygiene practices (**Gaze and Robert, 2015**). This tool, based on a systematic approach to prevent food risks, applies to all entities in the food chain, regardless of their size and the complexity of their operations. It is included in all food safety standards (such as BRC, IFS, and, of course, ISO 22000).

According to the Algerian National Agriculture Agency has revealed, most agribusinesses fall into the group of small and medium-sized companies, most of which have not obtained formal basic training in food safety. Barriers and incentives to implement food safety management systems (FSMS) such as HACCP and ISO 22000 in the food manufacturing sector in Algeria have not yet been studied (**Boulfoul and Brabez, 2022**). Likewise, some food companies have adopted different programs such as HACCP and ISO 22000 based on HACCP (**Ministry of Industry, 2019**). Hence, the interministerial Decree of 15 Rabie Ethani 1442, corresponding to December 1, 2020, establishing the conditions and procedures for the implementation of the Hazard Analysis and Critical Control Points (HACCP) system (**Interministerial Decree, 2021**).

The analysis of products within the food and beverage industry, specifically foodstuffs, is essential for quality control. This process ensures that products meet the correct nutrient levels, contain the appropriate constituents, accurately represent their stated contents, and adhere to local and international regulations, as applicable. Additionally, the properties of the food—be it rheological, physiochemical, optical, sensory, flavor, stability, or otherwise—can also be determined using various analytical techniques during the research & development (R&D) phase of a product's life cycle, and by analyzing the product, it's properties can be tuned (**Critchley, 2019**).

Testing all the essential characteristics of both raw materials and processed foods on the entire volume is practically unfeasible and is typically performed on a specifically chosen portion of the overall product volume, known as samples. Sampling involves selecting a portion that is representative of the entire lot, with the total quantity from which the sample is obtained termed as the population. The assumption is that the quality of the selected portion is indicative of the entire lot. Analyzing samples, rather than the entire population, allows for a quicker estimate of quality, with reduced expenses and personnel time. This approach is particularly advantageous as many analytical methods are destructive. Simultaneously, employing an appropriate sampling technique is crucial to ensure that the measured sample quality accurately and precisely represents the population (**Ramos, 2020**).

Food safety is of paramount importance, with most consumers invested in knowing what is in the products they consume and their nutritional value. However, consumers may not always trust that the information on a packet is correct, and a number of high-profile cases involving inaccurate labeling have highlighted this issue (**Singh and Mondal, 2019**).

Food labels and advertisement are direct means for sellers to communicate product information to buyers. Food label also allows the consumers to make safe and wellinformed choice about the food they consume. Food labelling as an effective tool to protect consumer health in terms of food safety and nutrition. Food labels convey information about the product's identity and contents, and on how to handle, prepare and consume it safely (**FAO, 2023**).

The Hazard Analysis and Critical Control Point (HACCP) system forms the cornerstone of modern food safety management systems (FSMS). Much has been written about HACCP and there are several more detailed texts that readers should consult if wishing to develop and implement an HACCP system. However, no book on hygiene control is complete without a discussion of HACCP systems and this chapter aims to meet that requirement, providing a summary of the application and use of HACCP in modern food businesses and an examination of how it links with other elements of food safety control (**Wallace and Mortimore, 2016**). It is important for businesses to stay informed about the latest regulations and standards in their field, to comply with regulatory requirements, and to establish effective compliance systems to ensure that their food products are safe and meet the current standards.

The present course is organized into six chapters. The first chapter outlines standardization of food analysis techniques. The second chapter details mandatory and optional labeling information, as well as claims on the labels of prepackaged food products. The third chapter focuses on the quality system and food safety. The fourth chapter discusses the labeling of prepackaged foods according to the Codex General Standard. The fifth chapter details the Hazard Analysis and Critical Control Points (HACCP) system. The last chapter presents a model for implementation in a food company: a case study in an Algerian company.

Chapter I.

Standardization of Food Analysis Techniques

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1. Introduction

Food analysis is the discipline dealing with the development, application and study of analytical procedures for characterizing the properties of foods and their constituents. By analysis, information about the different characteristics of foods, including their composition, structure, physicochemical properties and sensory attributes can be obtained. Food quality refers to the characteristics of food that is desirable and acceptable to consumers. It can be physical, chemical
or sensory. Quality control is not an option in food processing. Every batch of food produced by a company should have achieved the quality standards set by it. Quality should always be consistent.

2. Food Analysis - Need and importance

All food products require analysis at various stages right from reception of raw materials through production and sometimes even after the product reaches the market. Food is analysed by government agencies, food industries and researchers for various needs and reasons, which are discussed below. Food products are analyzed for a variety of reasons, including complying with legal and labeling requirements, to assess product quality, to determine nutritive value, to detect adulteration, and for research and development purposes (**Giese, 2004**).

2.1. Food Safety

The primary and most crucial purpose of food analysis is to guarantee its safety. Consumers expect their food to be safe above all else. The necessity for food safety testing has grown significantly due to the increasing number of contamination incidents. Recent global alerts include cases such as melamine found in milk products, carbendazim in orange juice, fish contaminated with PCBs (polychlorinated biphenyls), mercury-tainted milk powder, and unauthorized food ingredients in food supplements. Implementing rigorous quality control procedures during analysis is imperative to ensure the safety of products throughout the entire food supply chain, from production to consumption.

A food may be unsafe due to the presence of three different types of hazards namely

i. Biological hazard - harmful microbes (e.g., Listeria, Salmonella)

ii. Chemical hazard - toxic chemicals (e.g., pesticides, herbicides)

iii. Physical hazard - extraneous matter (e.g., glass, wood, metal, insect matter).

It is the responsibility of the manufacturer to ensure that harmful substances are not present in the food he produces. This can be achieved by following good manufacturing practices, sticking to regulations specified by the government for specific food products and by having analytical techniques that are reliable and capable of detecting harmful substances.

Many food industries aim to ensure food safety by implementing systematic quality programs such as Hazard Analysis and Critical Control Point (HACCP). HACCP identifies specific hazards and their control measures, emphasizing prevention rather than relying solely on end-product testing. Figure 1, illustrates the prerequisites for implementing the HACCP program and achieving safe food. Food manufacturers and government laboratories regularly analyze food products to confirm their absence of harmful substances and to ensure proper operation of the food production facility.

Figure 1. Safe food through HACCP.

2.2. Ensuring quality

The food industry sector has become highly competitive due to increased consumer and buyer awareness regarding the importance of safe and high-quality products. This awareness has prompted companies to focus on the quality of their products. To achieve this, the food industry must employ analytical methods throughout the entire food supply chain, starting from the raw ingredients to the final product. For example, when a consumer files a complaint about a specific characteristic of a product, it is the manufacturer's responsibility to analyze the complaint sample and identify the issue. This analysis not only helps in addressing the immediate problem but also enables the manufacturer to prevent similar issues in the future. The table below illustrates the various areas and situations in the food industry where analysis is necessary.

3. Types of Samples Analyzed

The chemical and physical analysis of foods plays a vital role in quality assurance programs within the food processing industry, spanning from the examination of ingredients and raw materials, throughout the processing stages, up to the evaluation of the finished products [4, 5]. This analysis is equally crucial when formulating and developing new products and assessing novel processes for food production. It also helps in pinpointing the source of problems associated with substandard products (refer to Table 1). The analysis of competitors' samples, such as store brands versus national brands, has become increasingly relevant.

For each type of sample mentioned in **Table 1**, the analysis might involve determining one or several components. The specific method of analysis can be influenced by the nature of the sample and the intended use of the obtained information. For instance, samples used for process control are typically analyzed using rapid methods, while determining nutritive value information for nutrition labeling generally necessitates more time-consuming analysis methods endorsed by scientific organizations. Analyzing various types of samples within a food processing system can provide answers to critical questions outlined in Table 1.

Tableau 1. Types of samples analyzed in a quality assurance program for food products (**Nielsen, 2017**)

Sample Type	Critical Questions
Raw materials	Do they meet your specifications? Do they meet required legal specifications? Will a processing parameter have to be modified because of any change in the composition of raw materials? Are the quality and composition the same as for previous deliveries? How does the material from a potential new supplier compare to that from the current supplier?
Process control sample	Did a specific processing step result in a product control of acceptable composition or characteristics? Does a further processing step need to be modified to obtain a final product of acceptable quality?
Finished product sample	Does it meet the legal requirements? What is the nutritive value, so that label information can be developed? Or is the nutritive value as specified on an existing label? Does it meet product claim requirements (e.g., "low fat")? Will it be acceptable to the consumer? Will it have the appropriate shelf life?
Competitor"s sample	What are its composition and characteristics? How can we use this information to develop new products?
Complaint sample	How do the composition and characteristics of a sample complaint sample submitted by a customer differ from a sample with no problems?

4. Reasons for analyzing foods

Consumer trends and demands, national and international regulations, and the food industry's need to manage product quality dictate the need for analysis of food ingredients and products and explain the types of samples analyzed.

4.1. Regulations

Food industries are under exceptionally rigorous regulations concerning the quality and safety of their products, and this strict oversight is entirely justified. The repercussions can be severe if contaminated food finds its way into the retail market. Due to increasing concerns about food and health safety, regulatory authorities have established strict mandatory standards regarding the presence

of various toxic substances. If these substances exceed the prescribed residual levels, they could pose significant risks to human health. It is crucial that all food products intended for domestic trade and international export adhere to the regulatory standards, ensuring that different toxicants in various food items remain within the prescribed limits.

4.2. Protecting consumers

Consumer protection is a top priority in the food and beverage sector. Analytical techniques are employed to screen both ingredients and finished products before they reach consumer shelves. For instance, polymerase chain reaction (PCR) tests can identify foodborne pathogens and viruses in products like lettuce. Laboratory tests are conducted to detect toxins left by pesticides and herbicides, as well as traces of metal, wood, glass, and other contaminants. These measures ensure the safety and quality of products available to consumers, reflecting the industry's commitment to consumer well-being.

4.3. Preventing food fraud

Food fraud is a global issue that affects consumers, product manufacturers and ingredients suppliers. The 2013 horse meat scandal is one of the most high-profile cases of food fraud, with the Food Safety Authority of Ireland initially detecting horse DNA in samples of frozen ready meals and burgers supposedly containing beef.

4.4. Research and Development

Various scientists and researchers throughout the world are continuously analysing food materials for better understanding of their properties so that improvement can be done during their processing. Their research is mainly directed towards investigating the structure and interaction of food ingredients, and how they are affected by changes in temperature, pressure and mechanical agitation. Scientists working for food companies are usually involved in product development. These scientists help improve existing products or develop new products.

5. Characteristics of the analysis method

There are often numerous methods available for analyzing specific characteristics or components in food samples. When selecting or modifying methods for determining the chemical composition and properties of foods, it is essential to understand the underlying principles and critical steps of the procedures. Certain properties and criteria outlined in **Table 2** can be valuable for assessing the suitability of a method currently in use or a new method under consideration. As emphasized in a food analysis review article by **Cifuentes (2012),** there is a constant need for the development of methods that are more robust, efficient, sensitive, and cost-effective. Many traditional "wet chemistry" methods have evolved into powerful and widely adopted instrumental techniques. This evolution has significantly improved accuracy, precision, detection limits, and sample processing speed.

Tableau 2. Criteria for choice of food analysis methods: method characteristics (**Nielsen, 2017**)

Characteristic	Critical questions
Inherent properties	
✓ Specificity/selectivity	Is the property being measured the same as that claimed to be measured, and is it the only property being measured? Are there interferences? What steps are being taken to ensure a high degree of specificity?
✓ Precision	What is the precision of the method? Is there within-batch, batch-to-batch, or day-today variation? What step in the procedure contributes the greatest variability?
✓ Accuracy	How does the new method compare in accuracy to the old or a standard method? What is the percent recovery? Is it reproducible between labs?
Applicability of method to laboratory	
✓ Reagents	Can you properly prepare them? What equipment is needed? Are they stable? For how long and under what conditions?
✓ Equipment	Is the method very sensitive to slight or moderate changes in the reagents? Do you have the appropriate equipment? Are personnel competent to operate equipment?
✓ Cost	What is the cost in terms of equipment, reagents, and personnel?
✓ Applicability to food/sample	Destructive or nondestructive? Online or off-line? Official method/approval? Nature of food matrix?
Usefulness	
✓ Time required	How fast is it? How fast does it need to be?
✓ Reliability	How reliable is it from the standpoints of precision and stability?
✓ Need	Does it meet a need or better meet a need? Simplicity of operation?
Personnel	
✓ Safety	Is any change in method worth the trouble of the change?
✓ Procedures	Who will do any required calculations?

6. Analytical procedure

The process of food analysis requires chemical assessments at various stages and for different purposes. From independent ingredients to processed products, chemical analyses and controls are crucial to ensure food quality. This becomes especially important during the development of new processing methods or the creation of new products. Similar to other analytical processes, chemical analysis in food involves vital steps that significantly impact the validity of generated data. While on-

site analysis is possible in specific cases, most samples need to be transported to a laboratory. Careful consideration of sample size, origin, and sampling protocol is essential to ensure the representativeness of samples and produce meaningful and interpretable data.

During transportation and storage, it's crucial that samples remain unchanged until the moment of analysis. Generally, samples should be stored for the shortest time possible. Stabilization procedures, such as retarding biological actions, chemical compound hydrolysis, and reducing volatilization or adsorption effects, should be applied when necessary.

Once in the laboratory, samples undergo various operations grouped under the term "sample preparation" before instrumental analysis of the target compounds. These operations depend on the nature and expected concentration of the target compounds, potential interfering components in the matrix, and the selectivity and sensitivity of the chosen analytical technique for separation and detection. Sample preparation involves labeling, mechanical processing, homogenization, and any gravimetric or volumetric measurements. It also includes treatments to break down the matrix structure for fractionation, isolation, and enrichment of the analytes under study. Additionally, procedures to make analytes compatible with the detector (such as phase changes and derivatization reactions) and enhance detector sensitivity are part of the sample preparation protocol (**Figure 2**).

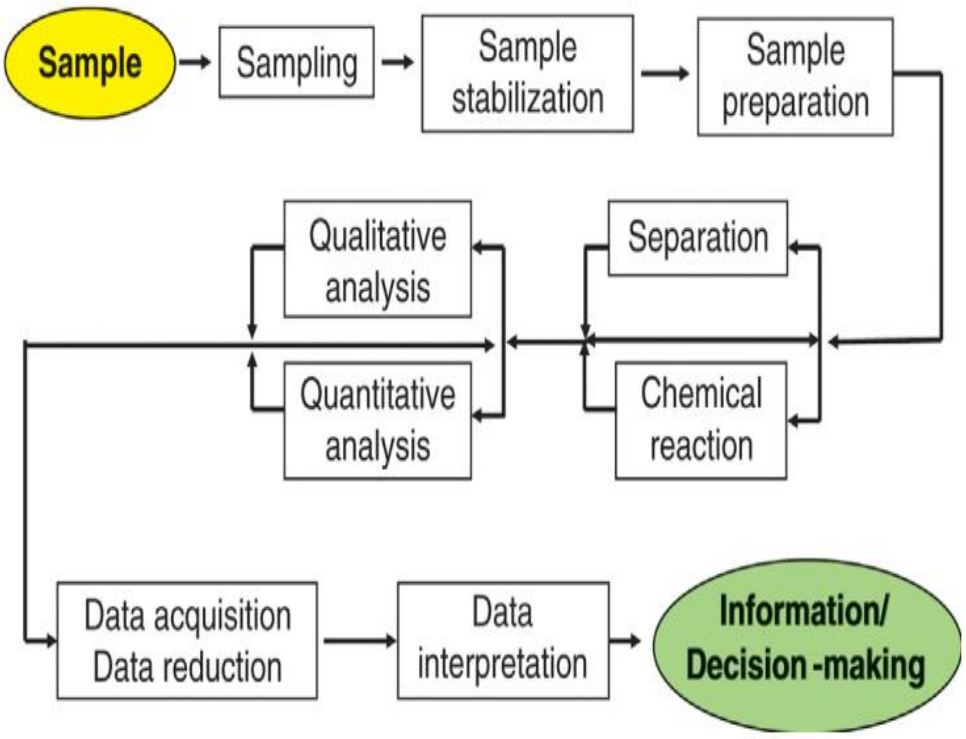

Figure 2. Steps in the analytical process (**Ramos, 2020**).

7. Validity of the analytical method

Numerous factors affect the usefulness and validity of the data obtained using a specific analytical method. One must consider certain characteristics of any method, such as specificity, precision, accuracy, and sensitivity.

However, it is essential to take into account the variability of data resulting from the method used for a specific characteristic. This consideration should be made in relation to the differences that can be detected and deemed acceptable to a consumer, as well as the inherent variability of the specific characteristic during food processing. The nature of the samples collected for analysis, their representativeness for the entire batch, and the number of samples analyzed all need to be carefully evaluated. Additionally, one should question whether the analytical procedure was meticulously followed, ensuring accuracy, repeatability, and comparability with previously collected data. To ensure the validity of the data, it is crucial that the analysis equipment is standardized, appropriately utilized, and that the performance limitations of the equipment are acknowledged (**Nielsen, 2017**).

7.1. Specificity

Specificity refers to the ability of a particular analytical method to detect only the interest component. Analytical methods can vary in specificity; they can be specific for a particular food component or can analyze a wide range of components. Sometimes, it is desirable for a method to be broad in its detection. For example, the analysis of food lipids (fats) involves identifying any compound soluble in an organic solvent, such as glycerides, phospholipids, carotenes, and free fatty acids. Since the goal is to determine the overall fat content and not each individual compound, a broad method is suitable.

However, in certain cases, a specific method is necessary. For instance, determining the lactose content in ice cream requires a specific method because ice cream contains various types of simple sugars. Without a specific method, the estimation of lactose content would be inaccurate due to the presence of other sugars.

There are no strict rules regarding the required level of specificity. It depends on the specific situation, desired results, and the type of assay being used. Nonetheless, the level of specificity is a crucial factor to consider when discussing various analytical techniques (**Smith, 2017**).

7.2. Sensitivity

Sensitivity refers to how much a measuring device (instrument) changes in response to variations in the concentration of a compound being measured. It indicates the smallest change in the unknown material that can be made before a noticeable difference appears on a needle gauge or a digital readout. An analogy often used is tuning a radio station on a stereo. Once the station is tuned in, the dial can be moved without disrupting the reception – this demonstrates sensitivity.

In many cases, the sensitivity of an assay can be adjusted to meet specific requirements. This means that we can modify the sensitivity based on whether we need more or less of it. Sometimes, a lower sensitivity is desired, allowing the analysis of samples with widely varying concentrations simultaneously (**Smith, 2017**).

7.3. Limit of Detection

The Limit of Detection (LOD) represents the smallest measurable increment with a certain level of confidence or statistical significance, distinct from sensitivity. In any assay, there is a lower limit at which point we are not sure if something is present or not. Ideally, it is preferable to concentrate the sample, moving away from this detection limit. However, circumstances may prevent this, necessitating knowledge of the LOD to work within its confines.

Various methods can gauge LOD, contingent on the equipment utilized. For instance, in instruments like spectrophotometers, gas chromatographs, or high-performance liquid chromatography (HPLC), LOD is typically achieved when the signal-to-noise ratio reaches 3 or higher. Put simply, when the sample value is three times greater than the noise level, the instrument has reached its lowest measurable limit. Noise, in this context, refers to the random signal fluctuations inherent in any instrument (**Shrivastava and Gupta, 2011**).

7.4. Limit of quantification (LOQ)

The Limit of Quantification (LOQ) signifies the lowest concentration of an analyte that can be accurately and precisely detected, based on predefined criteria set by assay developers. These criteria are not globally standardized, emphasizing the need to consider the clinical relevance of the assay when defining performance requirements.

The Lower Limit of Quantification (LLOQ) corresponds to the lowest calibration standard on the curve where the analyte response is at least five times greater than the blank. This response must be discrete, identifiable, and reproducible.

The calibration curve should not be extrapolated below the LLOQ or above the ULOQ (Upper Limit of Quantification) to determine the analyte concentration in unknown samples. The samples with concentrations higher than ULOQ must be diluted using the same biological matrix as an actual sample while those with concentrations below the LLOQ should be mentioned as the zero concentration.

7.5. Reproducibility

Reproducibility) is achieved through conducting multiple determinations of analyte concentrations using the specified Quality Controls (QCs) and, potentially, incurred samples.

8. Analytical methods

Consumers and industries demand that research communities implement assays that may help devise measures, including regulations, to address the aforementioned issues. This has prompted food scientists to explore new approaches and tools to tackle significant current challenges in food quality, safety, and authenticity (**Artavia et al., 2021**).

Sensory analysis, physicochemical techniques, and chromatography have countless applications and have been extensively documented. Microbiological analysis was also investigated in this section, which will serve as a primer for students to familiarize themselves with and comprehend the vast capabilities of these techniques. The section includes selected real applications in the food and feed industries, using the most representative and recent examples (**Figure 3**). The methods below represent approaches that have already been developed or are currently being implemented in our laboratories.

Figure 3. Representation of selected analytical methods and targets to exemplify applications in quality, safety, and authenticity of foods (**Artavia et al., 2021**).

8.1. Food Sensory Analysis

Sensory analysis, referred to as organoleptic evaluation, is a scientific method that provides objective information on how products are experienced by the consumer. It can be used to assess food and beverage beyond regulatory requirements or general safety and quality concerns, using the senses and statistical analysis to record insights. This method of testing evaluates the entire sensory experience of edible products – appearance, aroma, taste, and texture – in an objective, systematic manner (**Figure 4**).

Sensory analysis can be used for quality control, determining shelf life, gauging the readiness for product launch, assessing product success, flavor profiling, and identifying the attributes driving consumer preferences. It can be used to make important decisions around raw materials, ingredients, or additives and to make decisions about things like storage or packaging conditions, expiration or "best by" dates and product optimization.

Using sensory analysis to assess food products provides valuable information and insights that can be utilized to:

- ✓ Ensure consumer expectations are met or exceeded;
- ✓ Provide answers to very important questions about your products that translate directly to revenue and market success;
- ✓ Assess consumer insights to make impactful decisions about current products and product development;
- ✓ Troubleshoot problems;
- ✓ Gain competitive edge by comparisons to other brands.

Sensory analysis has become increasingly accepted as a standard component of food testing. More and more, it is viewed as imperative for helping to ensure the quality and market success of food products. It can be applied at various stages of production and product development.

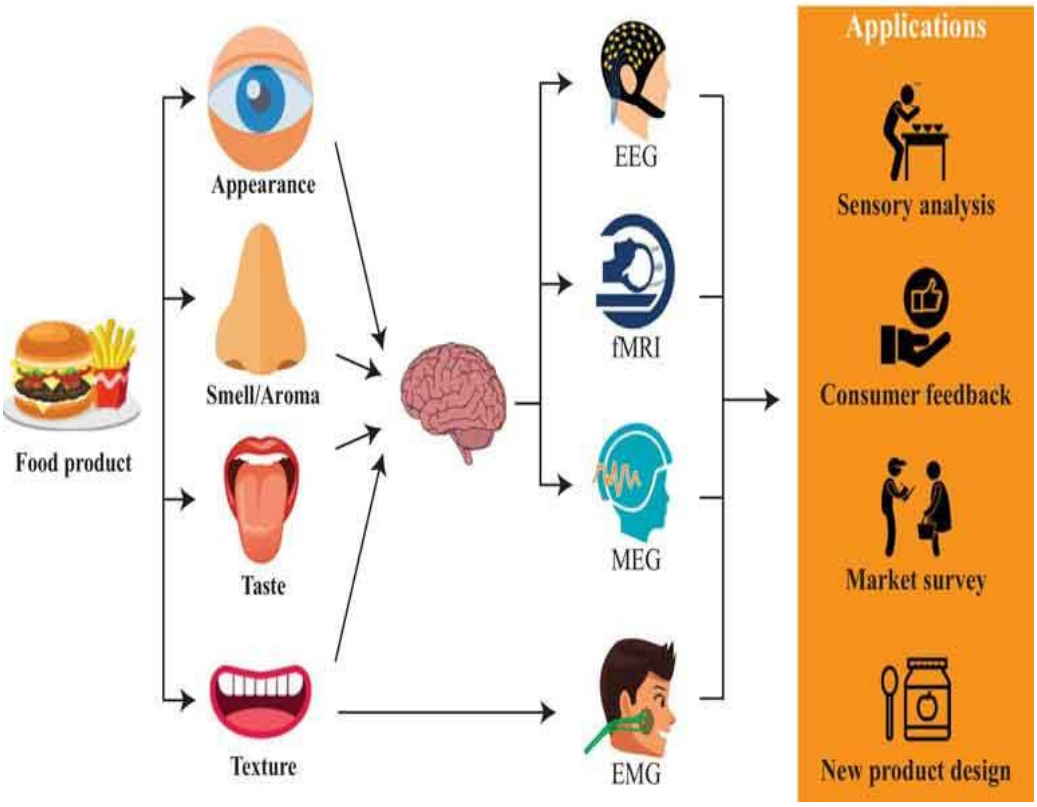

Figure 4. Sensory analysis (**Anbarasan, 2007**)

8.2. Physicochemical analysis technique

Physicochemical methods refer to a set of analytical techniques that investigate the physical and chemical properties of substances. These methods are widely used in various scientific disciplines, including chemistry, biology, environmental science, and material science. Here is a description of some common physicochemical methods:

8.2.1. pH measurement

The pH, potential hydrogen, is the measure of the acidity or basicity of a solution. It is a quantity without unit which makes it possible to measure the activity of the hydrogen ion (abbreviated by the chemical symbol H^+) in a solution.

pH is important in the food industry, as it plays a role in the taste (acid = fresh, neutral = bland, and alkaline = inedible) and the preservation of food. In biotechnology, pH must be closely monitored during the production of immunoassay solutions. These are just a few of the many applications in which pH is a valuable measurement.

8.2.2. Titration

Titration is the quantitative addition of a solution of known concentration to a solution of unknown concentration until the reaction between them is complete to determine the concentration of the second solution. An acid–base titration is the quantitative determination of the concentration of an acid or a base. Titration of an acid with a base requires that the pH, or relative concentrations

of the two reactants, be monitored. pH can be assessed by litmus paper or by indicators, for example, phenolphthalein, but these methods lack precision. Typically, pH measurement in the laboratory is done by measuring the cell potential of that sample in reference to a standard hydrogen electrode. A plot of the pH of an acidic (or basic) solution as a function of the amount of added base (or acid) is a titration curve. From this, the endpoint or equivalent points can be determined.

It is applicable to:

Quality Control: Determining the concentration of a known substance in a sample.

Analytical Chemistry: Quantifying the concentration of an unknown substance.

Environmental Analysis: Assessing the presence of pollutants in water samples.

8.3. Chromatography techniques

8.3.1. Gas chromatography

Gas chromatography is a column chromatography technique in which the mobile phase is gas, and the stationary phase is either an immobilized liquid or a solid packed in a closed tube. GC is valuable for the separation of thermally stable volatile components in a mixture, such as fatty acid methyl esters. In gas–liquid GC, the sample is vaporized and injected into the head of the column. A controlled temperature gradient facilitates the sample's movement through the column by the mobile phase, typically an inert gas. The volatile components are then separated based on boiling point, molecular size, and polarity.

GC has been extensively employed for determining fatty acids, triglycerides, cholesterol, and other sterols, as well as gases, solvent analysis, water, alcohols, and simple sugars. Additionally, it has been applied to analyze oligosaccharides, amino acids, peptides, vitamins, pesticides, herbicides, food additives, antioxidants, nitrosamines, polychlorinated biphenyls, drugs, flavor compounds, and many other substances. The versatility of GC makes it a powerful analytical tool for precise separation and identification of diverse compounds in complex mixtures.

8.3.2. High-performance liquid chromatography

High-performance liquid chromatography (HPLC) can be applied to the analysis of any compound with solubility in a liquid that can be used as the mobile phase. Although most frequently employed as an analytical technique, HPLC may also be used in the preparative mode (**Figure 5**).

There are numerous advantages of HPLC over traditional low-pressure column liquid chromatography:

- ✓ Speed, because many analyses can be accomplished in 30 min or less;
- ✓ a wide variety of stationary phases;
- ✓ improved resolution and greater sensitivity, because various detectors can be employed;
- ✓ easy sample recovery, because of less eluent volume to remove.

A basic HPLC system comprises a pump, injector, column, detector, and data system. HPLC is widely used for the analysis of small molecules and ions, such as sugars, vitamins, and amino acids. Additionally, it is applied to the separation and purification of macromolecules, such as proteins and polysaccharides.

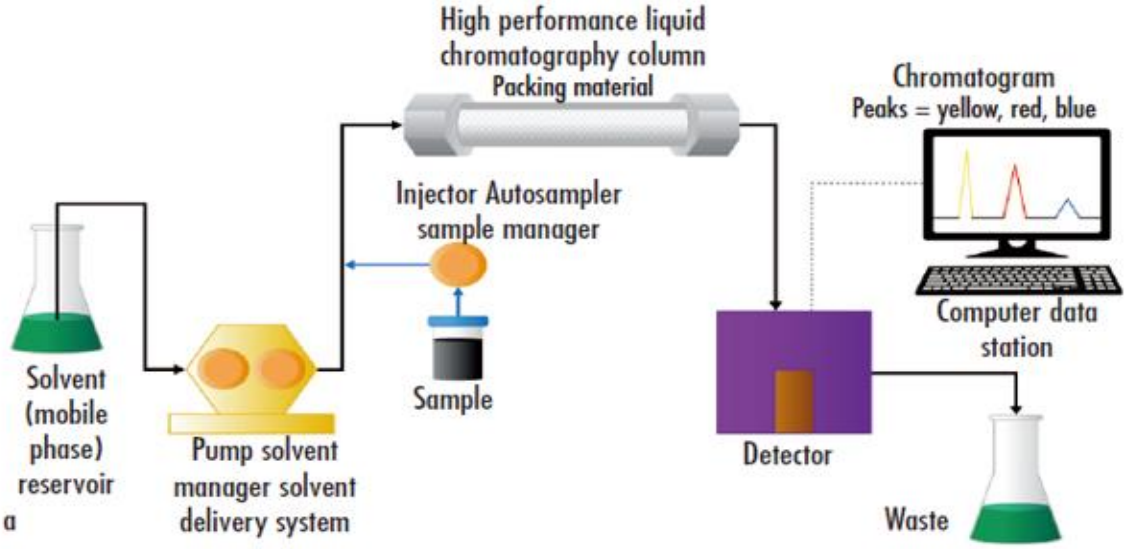

Figure 5. High-performance liquid chromatography technique

8.3.3. Gas Chromatography-Mass Spectromatry (GC-MS)

Gas Chromatography–Mass Spectrometry (GC-MS) is a hyphenated analytical technique that combines the separation properties of gas-liquid chromatography with the detection capabilities of mass spectrometry to identify various substances within a test sample. GC is employed to separate volatile and thermally stable compounds in a sample, while GC-MS fragments the analyte for identification based on its mass. The additional incorporation of a mass spectrometer leads to GC-MS/MS, where superior performance is achieved through single and triple quadrupole modes.

Foods and beverages naturally contain numerous aromatic compounds, either in their native state or formed during processing. GC-MS is exclusively utilized for the analysis of esters, fatty acids, alcohols, aldehydes, terpenes, and more. GC-MS is also employed to detect and measure contaminants, spoilage, and adulteration in food products such as oil, butter, and ghee. These analyses are crucial for ensuring safety and compliance with regulations set by governmental agencies.

GC-MS is applied in the analysis of various substances, including piperine, spearmint oil, lavender oil, essential oils, fragrance reference standards, perfumes, chiral compounds in essential oils, fragrances, menthol, allergens, olive oil, lemon oil, peppermint oil, ylang-ylang oil, strawberry syrup, butter triglycerides, and residual pesticides in food. This comprehensive analytical approach aids in quality control and regulatory adherence across a wide range of food and beverage products (**Figure 6**).

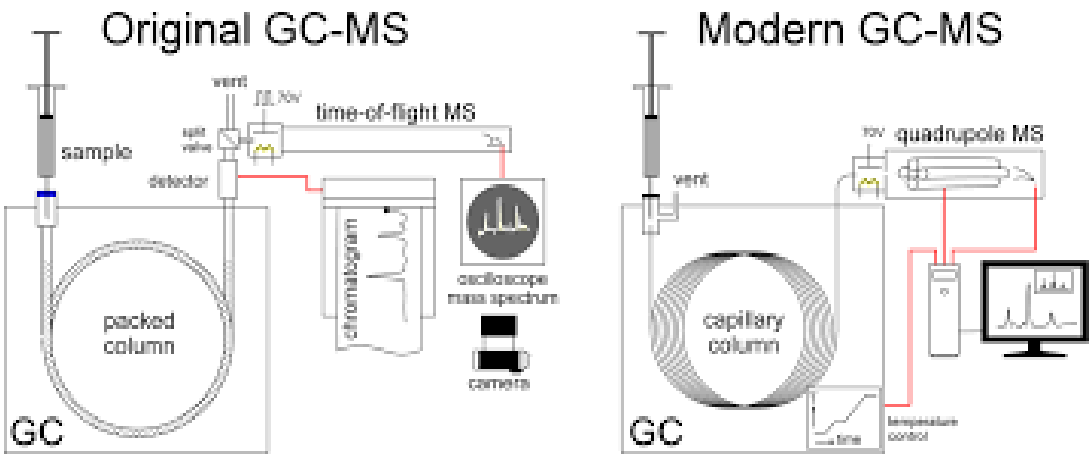

Figure 6. Gas Chromatography-Mass Spectromatry (GC-MS) technique

8.3.4. Infra-red (IR) spectroscopy

Infra-red spectroscopy is used to measure IR radiation absorbed by or reflected from a sample. The absorption of IR radiation is related to the changes of vibrational or rotational energy states of molecules. Its applications for analysis of gaseous, liquid or solid samples, identification of compounds and their quantitative analysis etc. The IR spectrum obtained for functional groups of molecules, constitution of molecules and interaction among molecules provides information about the samples (**Figure 7**).

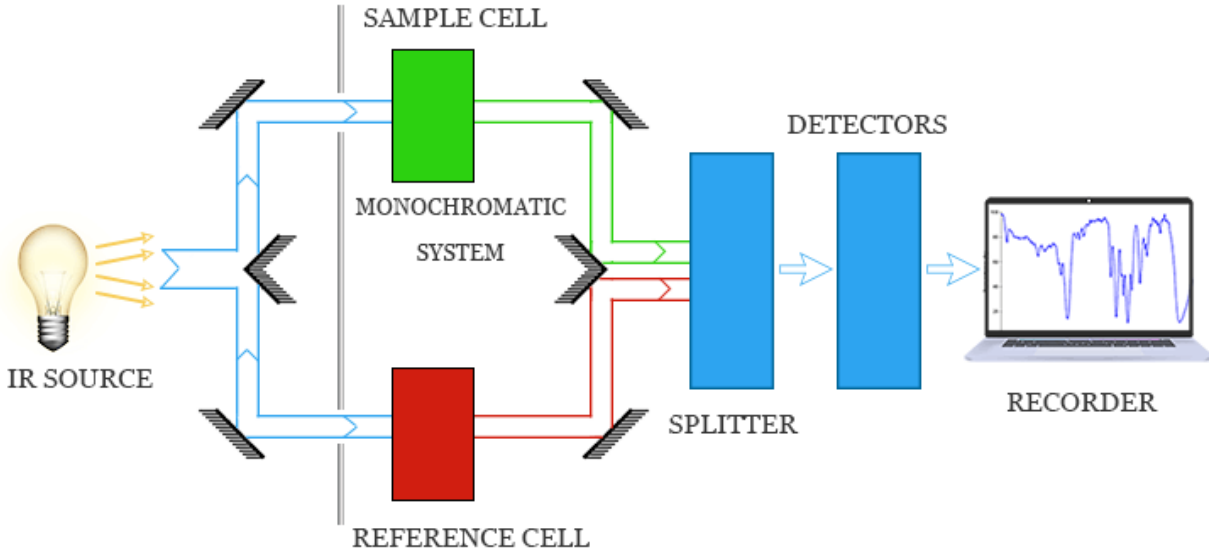

Figure 7. Infra-red (IR) spectroscopy technique

8.3.5. Supercritical fluid chromatography

Supercritical fluid chromatography (SFC) refers to chromatography that is performed above the critical pressure (Pc) and critical temperature (Tc) of the mobile phase. A supercritical fluid (or compressed gas) is neither a liquid nor a typical gas. The combination of Pc and Tc is known as the critical point. A supercritical fluid can be formed from a conventional gas by increasing the pressure or from a conventional liquid by raising the temperature.

SFC offers a wide ranges of selectivity adjustment, by changes in pressure and temperature as well as changes in mobile phase composition and the stationary phase. SFC makes possible separation of nonvolatile, thermally labile compounds that are not amenable to GC. SFC can be performed by using either packed columns or capillaries, and has used primarily for nonpolar compounds. Fats, oils, and other lipids are compounds which SFC is increasingly applied (**Figure 8**).

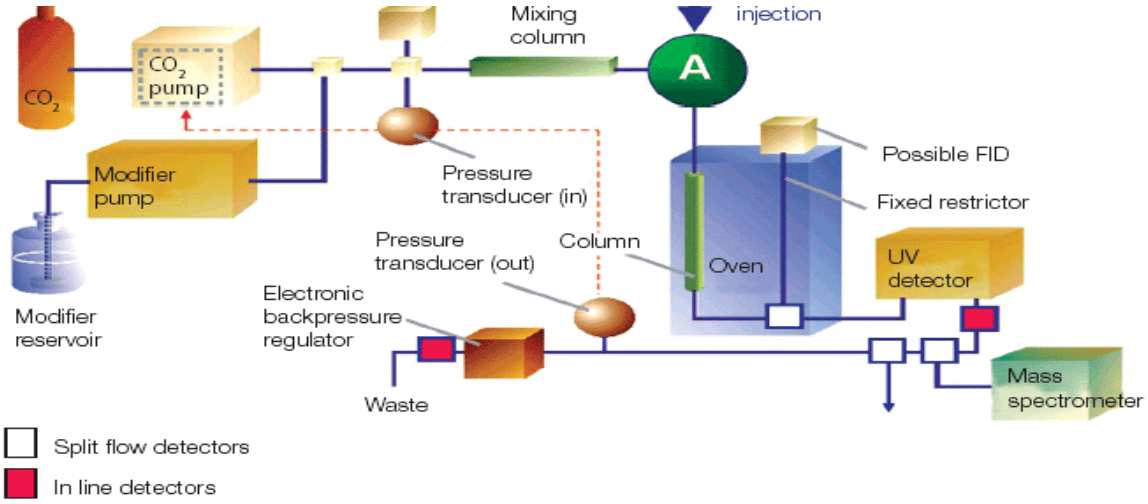

Figure 8. Supercritical fluid chromatography technique (**Berger, 2015**)

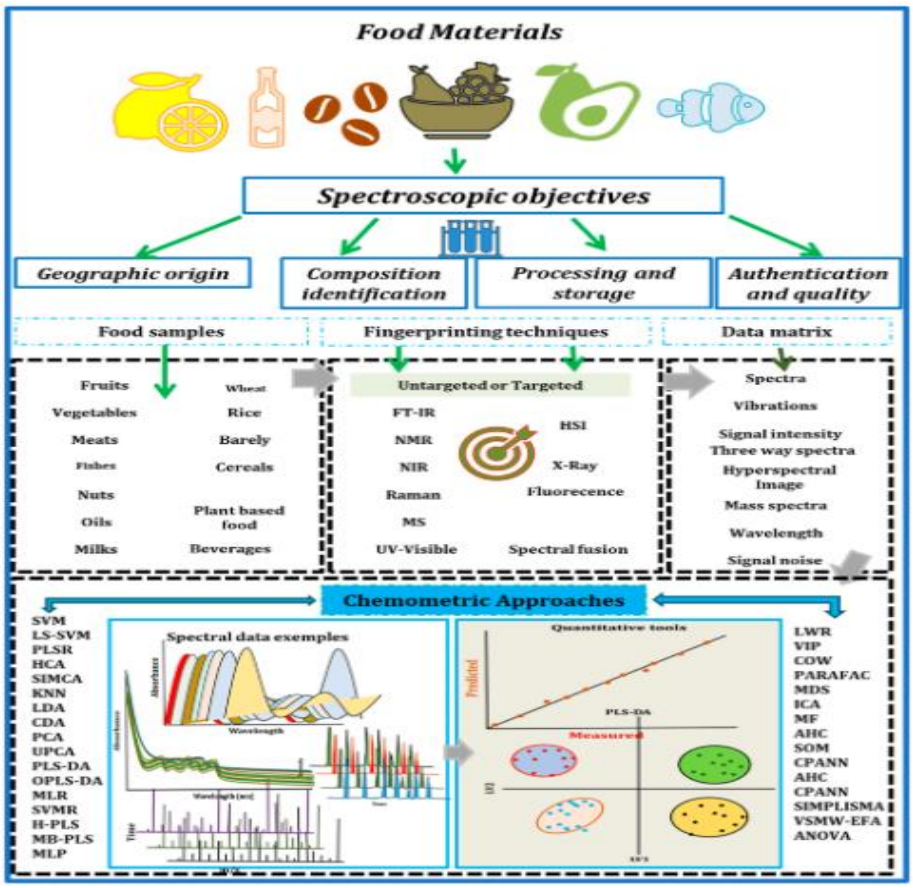

Figure 9. A general workflow of advanced spectroscopic techniques combined with chemometric approaches for food analysis

8.4. Microbiological Analysis Techniques

It is customary to distinguish between two types of techniques in microbiology, classified as traditional and speedy.

8.4.1. Traditional Techniques

The traditional techniques of Pasteurian microbiology are based on inoculating a sample into a specific medium for cultivation. The composition of the medium, incubation temperature, and the atmosphere in which the medium is incubated create a selective pressure, allowing the selective cultivation of a bacterial population. These methods serve as references and are internationally standardized. In the case of enumeration techniques, the sample undergoes successive decimal dilutions, and an inoculum from each dilution is used to inoculate a medium, either liquid or solid. After incubation, colonies with characteristic appearances are counted, and potential confirmation is done through biochemical tests.

For research techniques, such as those used for salmonella, a series of pre-enrichment and enrichment steps ensure the revival of stressed bacteria and selectively promote their growth. Subsequently, selective isolation and biochemical characterization are carried out based on colonies with characteristic appearances.

Traditional methods have the significant drawback of providing results only after several days. This observation explains the rise of so-called rapid techniques.

8.4.2. Speed Techniques

Speed techniques, depending on the case, aim to reduce response time or simplify manipulations, making them highly valued tools in the food industry.

Among the main rapid techniques used in food microbiology are:

- Immunological methods, mostly of the E.L.I.S.A. type.
- Molecular biology techniques, colony hybridization, or polymerase chain reaction (PCR).
- Impedance.
- Measurement of cellular adenosine triphosphate (ATP) or ATPmetry by bioluminescence.
- Image analysis processes after filtration and staining of samples and flow cytometry.

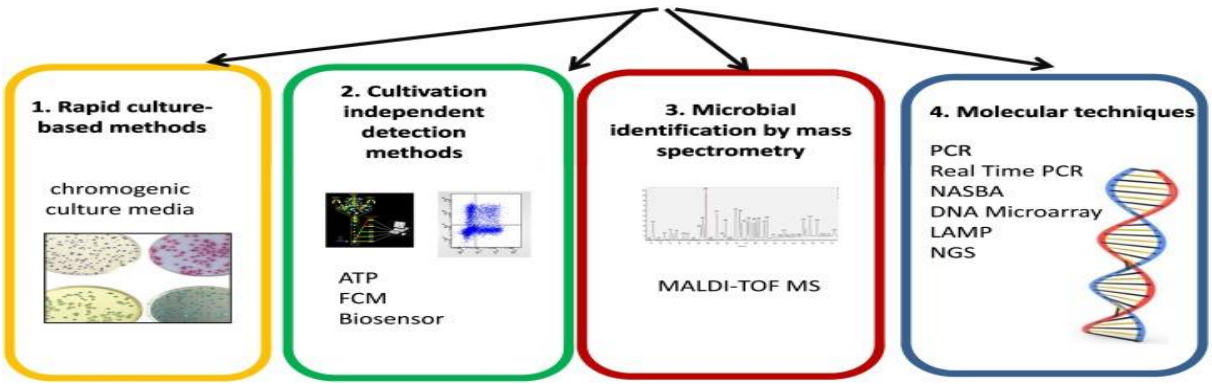

Figure 10. Different micobiological analysis techniques of food

Chapter II.
Sampling techniques

Chapter II. Sampling techniques

1. Introduction

Quality attributes in food products, raw materials, or ingredients are measurable characteristics that need monitoring to ensure specifications are met. The quality attributes are measured on small portions of material that are taken periodically from continuous processes or on a certain number of small portions taken from a lot. The small portions taken for analysis are referred to as samples, and the entire lot or the entire production for a certain period of time, in the case of continuous processes, is called a population. The process of taking samples from a population is called sampling. If the procedure is done correctly, the measurable characteristics obtained for the samples become a very accurate estimation of the population (**Morawicki, 2017**).

By sampling only a fraction of the population, a quality estimate can be obtained accurately, quickly, and with less expense and personnel time than if the total population were measured. in the case of food products, analyzing a whole population would be practically impossible because of the destructive nature of most analytical methods.

Sampling starts the series of steps needed to make decisions about data collected: sampling, sample preparation, laboratory analysis, data processing, and interpretation. In each step, there is a potential for error that would compromise the certainty, or reliability, of the final result.

2. Definition and Purpose of Sampling Plan

The International Union of Pure and Applied Chemistry (IUPAC) defines a sampling plan as: "A predetermined procedure for the selection, withdrawal, preservation, transportation, and preparation of the portions to be removed from a lot as samples"

A sampling plan should be a well-organized document that establishes the goals of the sampling plan, the factors to be measured, sampling point, sampling procedure, frequency, size, personnel, preservation of the samples, etc. The primary aim of sampling is to obtain a sample, subject to constraints of size that will satisfy the sampling plan specifications. A sampling plan should be selected on the basis of the sampling objective, the study population, the statistical unit, the sample selection criteria, and the analysis procedures. Depending on the purpose of the sampling plan, samples are taken at different points of the food production system, and the sampling plan may vary significantly for each point (**Morawicki, 2017**).

3. Factors Affecting the Choice of Sampling Plans

Each factor affecting the choice of sampling plans (**Table 3**) must be considered in the selection of a plan: (1) purpose of inspection, (2) nature of population, (3) nature of product, and (4) nature of test method. Once these are determined, a sampling plan that will provide the desired information can be developed.

Tableau 3. Factors that affect the choice of sampling plans (**reported by Morawicki, 2017**).

Factors to be considered	Questions
Purpose of the inspection	Is it to accept or reject the lot? Is it to measure the average quality of the lot? Is it to determine the variability of the product?
Nature of the population	Is the lot large but uniform? Does the lot consist of smaller, easily identifiable su bplots? What is the distribution of the units within the population?
Nature of the product	Is it homogeneous or heterogeneous? What is the unit size? How consistently have past populations met specifications? What is the cost of the material being sampled?
Nature of the test method	Is the test critical or minor? Will someone become sick or die if the population fails to pass the test? Is the test destructive or nondestructive? How much does the test cost to complete?

3.1. Purpose of Inspection

Sampling is typically conducted with a specific objective in mind, and this objective often influences the chosen sampling method. The main goals of sampling usually involve estimating the average value of a particular attribute and assessing whether this average aligns with the specifications outlined in the sampling plan. Different food industries have diverse sampling purposes, but the most crucial categories include the following:

1. Nutritional labeling
2. Detection of contaminants and foreign matter
3. Acceptance of raw materials, ingredients, or products (acceptance sampling)
4. Process control samples
5. Release of lots of finished product
6. Detection of adulterations
7. Microbiological safety
8. Authenticity of food ingredients.

3.2. Nature of Population and Product

To choose an appropriate sampling plan, it's essential to accurately define the population and comprehend the characteristics of the product slated for sampling. Populations for sampling are typically categorized as homogeneous or heterogeneous and can be discrete or continuous in nature. Additionally, both the population and the product can significantly differ in size.

The process of sampling in the food industry is complex due to the inherent heterogeneity in populations and products. Ideally, a homogeneous population, where every part is identical, simplifies sampling. However, true homogeneity is rare; even seemingly uniform products like sugar syrup can have subtle variations. Sampling plans and preparation methods must account for this heterogeneity. For discrete populations (divided into separate units like cans or boxes), sampling is relatively straightforward. In contrast, sampling from continuous populations (unseparated items like chips on a conveyor belt) is challenging. Population size varies from a single lot to entire warehouses, and conclusions drawn from one lot cannot be extended to others.

Addressing specific issues, like moisture content variation, requires a deep understanding of the production process. This awareness informs sample collection strategies. Sampling mycotoxins in food presents a unique challenge due to their random distribution. Precision in chemical analysis matters less than proper sampling techniques and thorough mixing before analysis. In this context, sampling methodologies play a critical role, emphasizing the importance of strategic approaches tailored to the nature of the population and the specific problem at hand in the food industry.

3.3. Nature of Test Method

The choice of a sampling plan is influenced by various characteristics of the procedures used to test collected samples, including cost, speed, accuracy, precision, and whether the test is destructive or nondestructive. Affordable, quick, nondestructive tests that maintain high accuracy and precision enable the analysis of numerous samples. However, if there are limitations in any of these characteristics, the nature of the test method becomes a more crucial factor in determining the appropriate sampling plan (**Figure 11**).

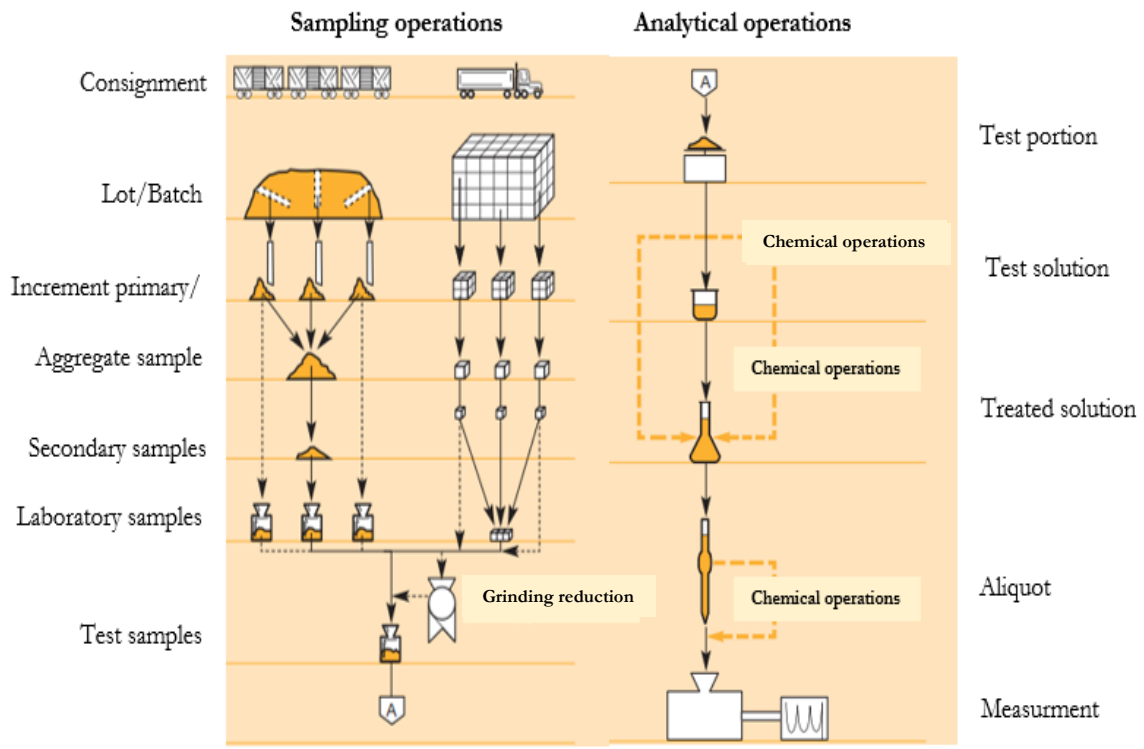

Figure 11. Relationship between sampling and analysis operations. The final sampling operation (A) continues with the initial analysis operation (A).

4. Sampling procedures

4.1. Probability sampling plans prescribe the selection of a sample from a population based on chance. It provides a statistically sound basis for obtaining representative samples with elimination of human bias. The probability of including any item in the sample is known and sampling error can be calculated. Several probability sampling methods are available to the researcher, and the most common ones are described in the next few paragraphs.

4.2. **Simple random sampling** requires that the number of units in the population be known and each unit is assigned an identification number. Then using a random selection process, a certain number of identification numbers are selected according to the sample size. The sample size is determined according to the lot size and the potential impact of a consumer or vendor error. The random selection of the individuals units is done by using random number tables or computer generated random numbers. Units selected randomly (sample) are analyzed and the results can be considered an unbiased estimate of the population.

4.3. Systematic sampling is used when a complete list of sample units is not available, but when samples are distributed evenly over time or space, such as on a production line. The first unit is selected at random (random start) and then units are taken every nth unit (sampling interval) after that.

4.4. Stratified sampling involves dividing the population (size N) into a certain number of mutually exclusive homogeneous subgroups (size N1, N2, N3, etc.) and then applying random or another sampling technique to each subgroup. Stratified sampling is used when subpopulations of similar characteristics can be observed within the whole population. An example of stratified sampling would be a company that produces tomato juice in different plants. If we need to study the residual activity of polygalacturonase in tomato juice, we can stratify on production plants and take samples on each plant.

4.5. Cluster sampling entails dividing the population into subgroups, or clusters, and then selecting randomly only a certain number of clusters for analysis. The main difference between cluster sampling and stratified sampling is that in the latter, samples are taken from every single subgroup, while in cluster sampling only some randomly clusters selected are sampled. The clusters selected for sampling may be either totally inspected or subsampled for analysis. This sampling method is more efficient and less expensive than simple random sampling, if populations can be divided into clusters. Going back to the tomato juice example, when using cluster sampling, we would consider all processing plants, but we would select randomly just a few for the purpose of the study.

4.6. Composite sampling is used to obtain samples from bagged products such as flour, seeds, and larger items in bulk. Small aliquots are taken from different bags, or containers, and combined in a simple sample (the composite sample) that is used for analysis.
Composite sampling also can be used when a representative sample of a whole production day in a continuous process is needed. In this case, a systematic approach is used to take equal aliquots at different times, and then a representative sample is obtained by mixing the individual aliquots. A typical example of composite sampling is the sampling plan mandated by the FDA and FSIS for nutritional labeling. They require a composite of 12 samples with at least six subsamples taken and analyzed for compliance with nutrition labeling regulations.

5. Preparing the protocols

Protocols are written documents that outline sampling operations, including the identification of foods, the weight and size of units to be sampled, the stratification to be used, and the distribution of sampling sites. The tables contain all the necessary information to prepare a sampling plan, starting with the description of the primary sample.

The volume of information resulting from this documentation may seem excessive, but based on experience, it is crucial to gather information on these different stages to subsequently assess the quality of both sampling and various analyses.

5.1. Food sample identification

The protocols are written documents that describe the sampling process: the identity of the food, the size and weight of units to be collected, the stratification to be used and the distribution of sampling sites.

Table 4 contains the necessary information. The first section serves as a label that should be securely and permanently affixed to the sample. The laboratory can then add a registration number. The majority of the required information is self-evident.

Tableau 4. Identification of the food sample

Common name of food	
Sample code numbre	
Date of receipt in laboratory	
Food identification	**Examples of record**
Alternative names	Other common names (in language of country of origin) and English equivalent where possible
Scientific name	Genus, species, variety
Plant food	Entire plant, or part of plant (Root, stem, leaves, flower, fruits, seeds)
Animal food	Entire animal, or part (leg, head, internal organ)
State of maturity	Immature, ripe, etc.
Grade	Where appropriate
Other details	Any details that the collector thinks may relevant

5.2. Record of collection

Table 5 describes the information to be recorded during the sampling of samples. The food records correspond to the sampling plan as specified in the combined protocols. They indicate the type of selected stratification and the method to ensure a random selection within the stratum. For this purpose, random number tables are very useful. The protocol must also specify the procedure to be followed if the defined sample is not available for collection. This may involve designating a replacement item or the necessity to choose an alternative sampling point.

Tableau 5. Food sample record for food composition studies: record of collection

Common name of food	
Sample code numbre	
Date of receipt in laboratory	
Collection details	**Examples of record**
Date of time collection	
Name of collector	
Place of origin	If known (village, district, province map reference)
Sampling point	Type (field, garden, roadside, stall, farm market, shop, warehouse, supermarket, take-away food bar, restaurant, household, deep sea, shoreline)
Adresse (es) of ampling point(s)	
Condition of cultivation	Where know (altitude, rainfall, fertilizer treatment, irrigation, feed regime)
Season	Time of year, dry of rainy season
Purchase price	If relevant
Graphical record	Visual record with scale ; line drawing may be sufficient
Transport condition	Details, including mode and condition of transport and storage
Other details	Any details that the collector considers relevant

5.3. Description of samples collected

The majority of the information listed in **Table 6** can be added once the samples have arrived at the laboratory, but details regarding local use and the preparation method must be included during the sampling process. It is essential to retain labels and ingredient lists as they provide key information that could prove useful in explaining analytical discrepancies (e.g., foods with no additional ingredients added but with incorrect labeling; and variations in the formulation of brand-name foods bearing the same names).

Tableau 6. Food samples file for studies on food composition : Description of the samples collected

Common name of food	
Sample code numbre	
Date of receipt in laboratory	
Description	Examples of record
Food type	Food grouping (legume, fruit juice, milk products, etc.)
Local use of food	In festivals, famine, etc.
Physical dimensions	
Physical state	Shape, form (e.g. liquid, solid, whole, divided, particle size)
Process and preservation method	Canned, smoked, sun-dreid, etc.
Preparation method for consumption	Cooking method
Extent of preparation	Raw, uncooked, partially cooked, fully cooked, thawed, reheated
Packing medium	Brine, oil, syrup, water
Container or wrapping	Can, glass, paper, foil, leaves
Contact surface	Glass, type of plastic, foil
Label or list of ingrédients	Retain label, estimated by inspection
Batch number	For branded foods
For branded or pre-packed food	
Weight of food collected	
Number of items	
Weight of individual items	
Weight of common measure or portion	
Other details	Any details that the recorder considers relevant (e.g. after fresh samples were collected they were vacuum sealed)

5.4. Record of handling in laboratory

The laboratory sample tracking process is described in **Table 7**, detailing the recording of the initial sample preparation steps leading to the preparation of samples for analysis. The laboratory may choose to incorporate its own internal identification code. Preserving the link between the sample identification number and any internal laboratory codes is crucial.

Throughout the entire handling phase, everyone should keep in mind the primary objectives of sampling, namely: ensuring the representativeness of the sample and preventing changes in its

composition or contamination. Thawing the samples carefully and handling them as quickly as possible is essential. It is advisable to repeat the operations as needed.

When separating the edible part from the non-edible part, cultural habits of the population consuming the food should be taken into account. The physical characteristics of the sample are among the important factors to consider when preparing samples. Pilot studies should also be conducted to check for homogeneity based on the chosen procedure and the absence of sample fractionation. Each food item should be examined on a case-by-case basis.

Tableau 7. Food sample file for studies on food composition : Laboratory handling record

Common name of food	
Sample code numbre	
Date of receipt in laboratory	
Handling stage	**Examples record**
Weight and nature of inedible matter	Prior to further preparation (e.g. head and feet of poutry, outer wilted leaves)
Weight and nature of edible matter	Prior to further preparation (e.G. remainder of poutry carcass)
Methode of preparation	Preparation of raw sample or cooking method, type, time, temperature and end(point temperature of foodstuff
Weight before cooking	
Ingredients added if any	
Weight after cooking	
Weight and nature of edible portion of prepared food	
Weight and nature of inedible material	Bone, gristle, etc.
Method of mixing and reduction	Grinding, homogenizing in blender (type of blades)
Detail of preparation of composite sample, if applicable	Simple mixing of equal weight of weighting of primary samples from the desgnated strata
Type of storage	Addition of preservatives, temperature of storage, etc.
Methode used to take analytical amples	
Storage of analytical samples or further processing	
Name and signature of person completing record	
Date of record	
Other details	Any detail that the collecor thinks may can be relevant

5.5. Storage of the analytical samples

The logistics of sampling preparation usually mean that it is more convenient to store the analytical samples prior to analysis. At least three sample replicates should be stored. Storage in a frozen state is usually the minimum acceptable with preference given to –40 or even –70 °C, which

is current common practice. Storage at –20 or –30 °C is acceptable for fat analyses. The container must be closely sealed with the minimum of headspace. When the samples are taken from storage any sublimed water above the sample must be carefully reincorporated in the mass.

Where freeze-drying is possible, storage of the freeze-dried samples in frozen or chilled conditions is satisfactory. Air-dried samples should be stored in such a way as to prevent uptake of water or contamination with insects or mites (**Table 8**).

Tableau 8. Effects of sample storage and preparation on nutrient content and precautions required to minimize them.

Effect	**Potentiel changes**	**Nutrients affected**	**Precaution**
Drying out	Loss of water	All nutrients	Design of protocol. Keep samples in sealed contrainers or covered. Weight food at stard ans during preparation
Absorption	Gain of water	All nutrients, especially in low-moisture and hygroscopic foods	Designe of protocol. Keep samples in sealed containers
Microbial activity	Degradation/autolysis synthesis	Losses of carbohydrates, proteins. Gains in thiamin, vitamin B_6, niacin and vitamine B_{12}	Storage at low temperature. Pasteurisation or addition of inhibitors may be necessary.
Oxidation	Destruction of unsaturated fatty acids. Loss of vitamins	Alteration in profile of fats Losses of vitamin C, riboflavin and folates	Store at -30°C in sealed containers under nitrogen. Addition of antioxidants or bacteriostatics agents
Acid	Hydrolysis	Losse of sucrose and higher oligosaccharides	Store at low temperature. Neutralize acid
Alkaline	Destruction	Loss of thiamin	Avoid alkaline conditions ans SO_2
Light	Photodegradation	Loss riboflavin	Protect from light
Contamination during sampling	From cooking vessels, soil, dust, etc.	Increases in inirganic nutrients	Design protocol to minimize contamination, gently rinse with distilled water
Contamination (from metallic blades, milling equipement, glassware, etc.)	Increse in inorganic nutrients	Increase in major trace elements	Select apparatus with care. Clean all utensils thoroughly before use ans store in plastic bags
Separation	Separation of fats. Fractionation of particles	Changes in composition overall, alteration in fibre content	Avoid overvigorous mixing and thaw/freeze cycles
Enzymatic and metabolic activity	Changes in organic nutrients	Losses of sugars, vitamin C, folate deconjugation	Store at low temperature. Protect folates with ascorbate

5. Main sources of errors during sampling

It is essential that everyone involved in the sampling process fully understands its objectives and their respective roles. To achieve this, it is necessary to repeat the procedures, even if only through a paper exercise. This will help identify aspects that are unclear or unfeasible and need to be modified.

Table 9. Summarizes the main errors encountered during sampling. These highlight the crucial importance of documentation, staff training, and supervision at various stages.

Tableau 9. Main errors encountered during sampling

Sources	**Exemple**	**Precautions**
Identification of the food sample	Inadequate labeling of samples	Conservation of documentation during sampling and analysis
Sample Nature	The samples do not conform to the established sampling protocol.	Explicit instructions in the sampling protocol, training for the personnel responsible for sampling
Transport and handling	Contaminated, degraded, or impoverished samples during transportation or storage. Loss of samples	The protocol specifies the conditions to be maintained, supervision.
Preparation of analytical samples.	Incorrect mixing or homogenization.	Appropriate supervision in the laboratory. Laboratory quality assurance systems.
Storage of analytical samples	Incorrect storage of samples	Proper laboratory techniques and supervision.

Chapter III.
Food Safety

Chapter III. Food Safety

1. Introduction

The scope of food safety has changed throughout human history. Managing food safety has become very challenging at the operational level as food production and consumption currently involve a chain of events that must be adequately performed to ensure food will not impair public health. The contemporary complexity of food safety can be explained by the fact that foods are currently traded not only on a regional scale but also on an international scale. In addition to the globalization of the food trade, other factors such as important changes in lifestyles and demographic compositions, adaptation of food-borne hazards, and changes in processing conditions and preservation methods help to explain how challenging food safety is nowadays (**Chaves *et al.*, 2017**).

To this extent, the system that provides food safety needs to meet the basic conditions given below:

a) *Availability*: Capacity of producing, storing, and importing the necessary amount of food to satisfy the needs of all groups.

b) Accessibility: To ensure the impacts of international and political imposition are at a minimum and to physically and economically ensure all can acquire food.

c) Sufficiency: An environment of trust which can get through seasonal and periodical threats to food acquirement and the food production being nutritional, safe, and environmentally sustainable.

d) Acceptability: Food supply being suitable to cultural habits, not hampering human rights and honor.

e) Individual and Institutional Factors: The institutions which are the policymakers and manage the whole process, with the responsibility of food safety (**Koc and Uzmay, 2015**).

2. Definition of Food safety

According to Codex Alimentarius Commission (**CAC, 2017**), food safety is to guarantee that food will not harm the consumer. To prevent food from being contaminated at any point of this "from stable to table, from plow to plate, from farm to fork, from boat to throat, from till to tooth and from spring to drink" continuum, the International Organization for Standardization (ISO) published a standard that describes the requirements for FSMS and involves quality management systems specially focused on safe and good quality food. Quality management systems suggested organizations to control and coordinate for quality by setting quality objectives and implementation of quality policy for food quality assurance with a system of continuous improvement.

3. Definition of Food Safety Hazards

The main classes of food safety hazards are shown in **Table 10**. The three groups of hazards mentioned are:

1. biological hazards (bacterial, toxin-producing organisms, parasites, viruses, and prions);
2. chemical hazards (pesticide residues, food additives, hormones, allergens, veterinary drug residues, chemical contaminants from packaging);
3. physical hazards (bone, metal fragments, glass, brittle plastics, jewelry, stones).

Among these, biological hazards are a cause of great concern compared to the physical and chemical hazards. The main reason for this is that biological hazards lead to acute symptoms (and sometimes death), resulting in an easier association of etiological agent and the disease. From the food processing point of view, it should be highlighted that there is a dynamic (growth, survival, inactivation) involving some biological hazards (microorganisms, for example). As such, for the effective control of biological hazards, efficient controlling strategies must be designed and validated (**Chaves *et al.,* 2017**).

Tableau 10. Food Safety Hazards

Biological Hazards	**Chemical Hazards**	**Physical Hazards**
Pathogenic bacteria	Mycotoxins	Stones
Viruses	Allergens	Bone fragments
Prions	Heavy metals	Wire pieces
Parasites	Pesticides	Broken glass
	Cleaning and sanitation chemicals	Wood splinters

4. Definition of Quality

From the consumers', several aspects contribute to defining the quality of a food product: these are not only intrinsic qualities such as taste and other organoleptic properties, but also external factors such as origin and labelling **(Sadílek, 2019).**

The ISO 9000:2000 norm defines the quality as the ability of a product, process or system to fulfil the requirements of the customer and all the involved parties (reported by **Bilska and Kowalski, 2014**).

Deming (1986), defines it as the degree of homogeneity and reliability of a product at the lowest possible cost and the highest possible conformity with the market's requirements.

5. Definition of food quality

Food products are distinct from industrial products. Their unique characteristics give rise to specific constraints in the agri-food sector **(Multon and Davenas, 1994).** From the consumers'

point of view, in fact, several aspects contribute to defining the quality of a food product: these are not only intrinsic qualities such as taste and other organoleptic properties, but also external factors such as origin and labelling.

6. Food Quality Components

Mainguy (1989) summarizes these different components of quality with four elements:

- ✓ Satisfaction, which corresponds to organoleptic aspects;
- ✓ Health, referring to nutrition;
- ✓ Safety;
- ✓ Service.

In addition to these fourth elements, it includes the Symbolic aspect conveyed by the food, as well as the 'Society' to emphasize the impact of social changes on eating habits **(Ispa, 2004).**

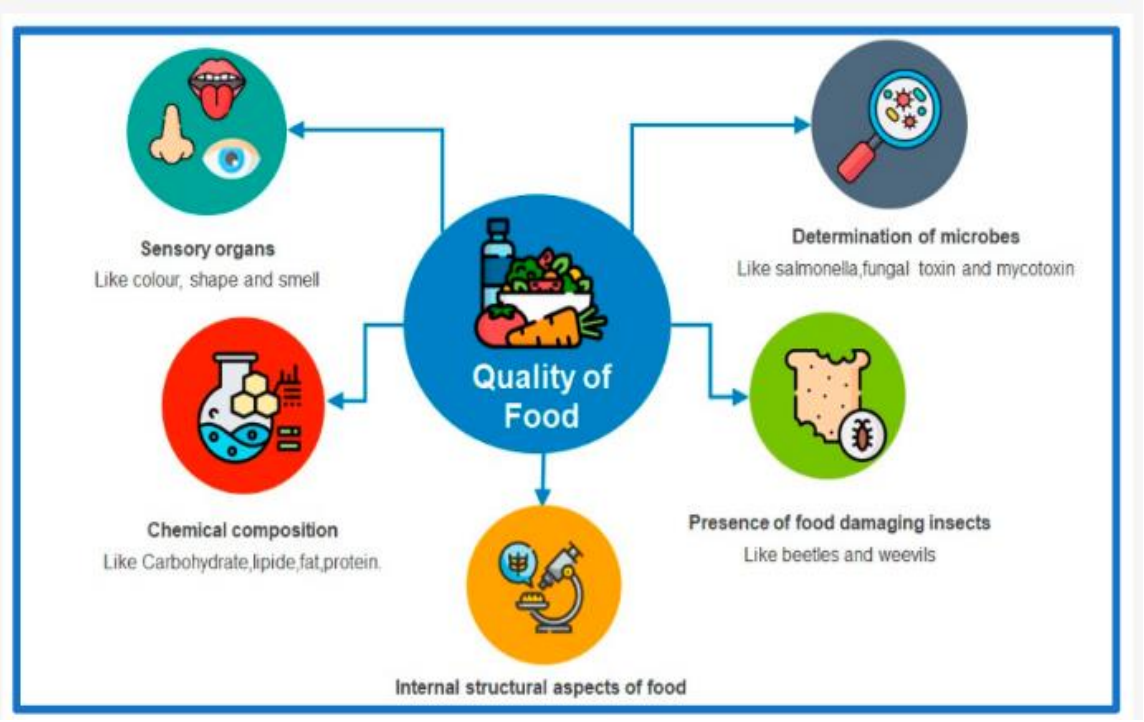

Figure 12. Factors affecting the quality of foods

6.1. Food Safety

Food safety is the assurance that food will not cause harmful effects to the consumer when prepared and/or consumed according to their intended use **(Codex alimentarius, 1969).**

While the incidence of foodborne illnesses related to the direct consumption of raw fruits and vegetables is low, the risks are real. The potential for high levels of pesticide residues on produce and the discovery of new emerging pathogens present new challenges for the fresh food industries **(Andrews 1999).**

6.2. Health (Nutritional Quality)

The presence of essential nutrients and all non-energy-yielding substances, as well as all aspects concerning food, encompasses other elements. These other aspects include non-essential amino acids, specific types of fatty acids and carbohydrates, dietary fibers (plant materials not digestible by human enzymes), cholesterol, lipotropic substances, and all components of breast milk (excluding drugs and other contaminants) **(*Codex alimentarius*, 1985).**

6.3. Flavor (Organoleptic Quality)

We seek to satisfy our five senses. This quality often influences the first two: Sometimes, we intoxicate ourselves because we enjoy it (e.g., alcohol, pufferfish); we can also upset our diet due to an excess or lack of taste (e.g., excess fats and sugary drinks in the USA, deficiencies in the elderly). Organoleptic quality has a major sensory component, which can be measured through sensory analysis (objectified by a panel of judges), but it also has a psychological and social component (the Dream) **(Corpet, 2014).**

Satisfying everyone can be challenging, so the manufacturer must target their market for the product and determine the sensory quality standard that suits it best **(Multon and Davenas, 1994).**

6.4. Service

A healthy, nutritious, and delicious food item may not sell well if it is too expensive, hard to find, difficult to prepare, or challenging to store (e.g., some exotic fruits). Therefore, we desire foods that have a long shelf life before and after purchase, and that are easy to use: for storage, opening/closing, and preparation.

A significant portion of the added value to food products by the agri-food industries focuses on their utility and service value (e.g., sophisticated packaging, ready-made meals) that are also affordable (**Corpet, 2014).**

4. Definition of hazards related to food safety

A hazard is defined as any biological, chemical, or physical agent present in a food product that can potentially have a harmful effect on the health of consumers (**ISO 22000**).

7. Traceability

For a food product, traceability represents the ability to identify the farm where it was grown and the sources of inputs, as well as the capacity to track the post-harvest history and pinpoint the exact location in the supply chain through records. Traceability is fundamentally a proactive approach to food quality and safety management, advocating the prevention of the introduction of new hazards into the supply chain. It complements quality control measures by facilitating the identification and isolation of risks and the implementation of effective corrective actions in case of incidents **(Opara et Mazaud, 2001).**

8. Quality Indicators

They influence the consumer's perception of product quality by serving as uncertainty reducers. Indicators such as price, brand, or store also provide assurance to the consumer. Similarly, indicators related to the country of origin or manufacturing address the consumer's need to establish a connection between the product and their representation of the production factors for these products. The inclusion of these mentions on the label plays the role of guaranteeing the product's origin for the consumer **(Branger and al, 2007).**

9. Quality Marks

The industry that produces "quality" wants it to be officially recognized (attested) and wants to make it known (to consumers). In a supermarket, the average shopper devotes about one second to the selection of a food item; therefore, quality must "stand out." The enterprise can achieve this by using its own brand or an official guarantee such as the "Label Rouge," the "Appellation d'Origine Contrôlée," AOC, or a conformity certification **(Corpet, 2014).**

Figure 13. Quality Marks

9.1. Controlled Designation of Origin (AOC: Appellation d'Origine Contrôlée)

The AOC, or "Appellation d'Origine Contrôlée," is a geographical indication used to designate a product that originates from a specific place and whose qualities are primarily influenced by the geographical environment, including natural and human factors. AOC designations are issued by the INAO, the National Institute of Origin Appellations.

A product bearing the AOC label is closely tied to its terroir, which includes factors such as climate, soil, and local traditions. It must possess a distinctiveness that is linked to the specific location, making it a product that cannot be replicated elsewhere.

The AOC designation was officially established in 1935 for wines and spirits. Since the 1960s, dairy products have also been included under AOC regulations, and starting from 1990, all categories of food products have the possibility to obtain AOC status.

9.2. Red Label (LR: Label Rouge)

The "Label Rouge" label indeed certifies that the product has specific characteristics that have been predefined, ensuring a higher level of quality compared to other similar products. It is used to recognize and distinguish products that meet these higher quality standards and have typically been produced using specific and traditional production methods. This allows consumers to make an informed choice by favoring higher-quality products.

Five conditions are necessary to establish a label:

1- An independent certifying body separate from the producer;

2- A written technical description of the product's superior quality;

3- A control plan based on the specifications;

4- Informative labeling on the products;

5- A sufficient volume placed on the market.

The label is not permanent but can be called into question if the conditions are no longer met.

9.3. Organic Agriculture (AB: Agriculture Biologique)

The "AB" label is defined for production methods (not the product)

- ✓ No synthetic products used (except for a positive list)
- ✓ Environmentally and animal-friendly methods, Recycling of organic matter Crop rotation No GMOs, Biological pest control
- ✓ Minimal inputs: farm-produced feed, non-confined animals
- ✓ Compound foods: over 95% of components from organic farming

The "AB" label involves four conditions (the same as the first four for labels):

1- Independence between the managing body and the producer

2- Very precise specifications for production methods

3- A control plan for compliance with specifications, including penalties

4- Official labeling and logo

9.4. Conformity Certification (CC: Certification de Conformité)

Conformity Certification certifies that a product complies with specifications, which include characteristics or rules related to manufacturing, processing, packaging, or origin. These characteristics must be measurable and documented in a specification document (public) or a standard (developed by AFNOR after consultation with all stakeholders; in this case, it carries the "NF" marking).

CC does NOT guarantee superior quality, but merely conformity to a standard.

10. Quality Assurance

Quality Assurance is the set of pre-established and systematic measures whose application and control instill confidence (i.e., ensure) that a product meets what is expected of it (i.e., quality).

Three 'major' useful standards:

ISO 9001:2000: International standards related to quality management constitute a family known as "ISO 9000." ISO 9001:2000, published in 2000 as its name suggests, replaces the previous standards: ISO 9001, 9002, 9003, and 9004.

ISO 22000: Food safety standard for the agri-food industry. It is discussed at the end of this course, along with the private reference standards IFS and BRQ.

ISO 14000: Environmental Standard. A standard aimed at improving a company's performance concerning water, air, waste, noise, and odors. This leads to pollution prevention and savings in resources (water, materials, energy).

10.1. Food quality standard (ISO 9001)

The ISO 9000 family of standards takes into account a variety of quality management aspects and involves some of ISO's most widely known standards. These standards guide and support companies and organizations through providing them with the tools they need to ensure that their products and services are consistent and in accordance with what their customers need, continuously improving at the same time the overall quality level of the organizations (**Kotsanopoulos and Arvanitoyannis, 2017**).

The ISO 9000 family includes standards such as:

(a)The ISO 9001:2015—that covers the requirements of a QMS.

(b) The ISO 9000:2015—that includes the basic concepts and language.

(c) The ISO 9004:2009—that focuses on improving the efficiency and effectiveness of a QMS.

(d) The ISO 19011:2011—that includes guidelines for the conduction of internal and external audits of QMS

According to **BSI (2014)**, "ISO 9001:2015 sets out the criteria for a QMS and is the only standard in the family that can be certified to (although this is not a requirement). It can be used by any organization, large or small, regardless of its field of activity. ISO 9001:2015 replaced ISO 9001:2008 and specifies the requirements for establishing, implementing, maintaining, and continually improving a QMS for any organization, regardless of type or size.

10.2. Food quality standard (ISO 22000)

ISO 22000 is an international standard for food safety that serves as a hybrid between ISO 9001:2000 The ISO 22000 standard and the HACCP (Hazard Analysis and Critical Control Points) system.

The ISO 22000 standard specifies requirements for five essential elements in food safety: systemic approach, interactive communication, traceability, prerequisite programs (PRP), and the HACCP plan.

Systemic Approach: The process is viewed as a whole, not just analyzed point by point.

Communication: It is established in both directions with suppliers, customers, regulatory authorities, and company personnel.

Traceability: The traceability is the ability to trace the history of an item through recorded identification. Traceability is therefore the capacity to track the journey of a food product from the primary producer to the customer.

Prerequisite programs (PRP): These are the basic hygiene rules necessary for the proper production of the product. They are not intended for controlling a specific hazard but rather for maintaining a high level of hygiene.

These elements collectively contribute to ensuring food safety within an organization's operations.

ISO 22000 is a standard applicable to all organizations in the agri-food sector. The purpose of this standard is to establish and maintain a genuine food safety management system. The standard emphasizes the skills of the personnel, the continuous search for information regarding food products (new laws, standards, regulations, etc.), and a return to the original HACCP system. ISO 22000 is compatible with ISO 9001:2000 (so a company already under ISO 9001 can easily transition to ISO 22000), with the addition of a "good" HACCP system. In essence, ISO 22000 = ISO 9000 Standard + HACCP.

Chapter IV.
Codex General Standard for the Labelling of Prepackaged Foods

Chapter IV. Codex General Standard for the Labelling of Prepackaged Foods

1. Introduction

Food labelling is the primary means of communication between the producer and seller of food on one hand, and the purchaser and consumer of the other. The *Codex Alimentarius* standards and guidelines on food labelling published in various volumes of the *Codex Alimentarius* are now collected and republished in this compact format to allow their wide use and understanding by governments, regulatory authorities, food industries and retailers, and consumers.

2. Definition of terms

For the purpose of this standard:

- ✓ **Claim:** means any representation which states, suggests or implies that a food has particular qualities relating to its origin, nutritional properties, nature, processing, composition or any other quality.
- ✓ **Consumer:** means persons and families purchasing and receiving food in order to meet their personal needs.
- ✓ **Container:** means any packaging of food for delivery as a single item, whether by completely or partially enclosing the food and includes wrappers. A container may enclose several units or types of packages when such is offered to the consumer.

For use in Date Marking of prepackaged food:

- ✓ **Date of Manufacture:** means the date on which the food becomes the product as described.
- ✓ **Date of Packaging:** means the date on which the food is placed in the immediate container in which it will be ultimately sold.
- ✓ Sell-by-Date" means the last date of offer for sale to the consumer after which there remains a reasonable storage period in the home.
- ✓ **Date of Minimum Durability**: ("best before") means the date which signifies the end of the period under any stated storage conditions during which the product will remain fully marketable and will retain any specific qualities for which tacit or express claims have been made. However, beyond the date the food may still be perfectly satisfactory.
- ✓ **Use-by Date:** (Recommended Last Consumption Date, Expiration Date) means the date which signifies the end of the estimated period under any stated storage conditions, after which the product probably will not have the quality attributes normally expected by the consumers. After this date, the food should not be regarded as marketable.

- ✓ **Food:** means any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drinks, chewing gum and any substance which has been used in the manufacture, preparation or treatment of "food" but does not include cosmetics or tobacco or substances used only as drugs.
- ✓ **Food Additive:** means any substance not normally consumed as a food by itself and not normally used as a typical ingredient of the food, whether or not it has nutritive value, the intentional addition of which to food for a technological (including organoleptic) purpose in the manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food results, or may be reasonably expected to result, (directly or indirectly) in it or its by-products becoming a component of or otherwise affecting the characteristics of such foods. The term does not include "contaminants" or substances added to food for maintaining or improving nutritional qualities.
- ✓ **Ingredient:** means any substance, including a food additive, used in the manufacture or preparation of a food and present in the final product although possibly in a modified form.
- ✓ **Label:** means any tag, brand, mark, pictorial or other descriptive matter, written, printed, stencilled, marked, embossed or impressed on, or attached to, a container of food.
- ✓ **Labelling:** includes any written, printed or graphic matter that is present on the label, accompanies the food, or is displayed near the food, including that for the purpose of promoting its sale or disposal.
- ✓ **Lot:** means a definitive quantity of a commodity produced essentially under the same conditions.
- ✓ **Prepackaged:** means packaged or made up in advance in a container, ready for offer to the consumer, or for catering purposes
- ✓ **Processing Aid:** means a substance or material, not including apparatus or utensils, and not consumed as a food ingredient by itself, intentionally used in the processing of raw materials, foods or its ingredients, to fulfil a certain technological purpose during treatment or processing and which may result in the non-intentional but unavoidable presence of residues or derivatives in the final product.
- ✓ **Foods for Catering Purposes:** means those foods for use in restaurants, canteens, schools, hospitals and similar institutions where food is offered for immediate consumption.

3. General principles

1. Prepackaged food must not be represented or described on labels or in any form of labeling in a manner that is false, misleading, or likely to create a wrong impression about its nature.
2. Furthermore, prepackaged food labels should not include words, images, or other elements that directly or indirectly allude to any other product, causing confusion or giving consumers the impression that there is a connection between the food and another product.

4. Mandatory labelling of prepackaged foods

The details provided below must be included on the label of prepackaged foods, tailored to the specific food being labeled, unless explicitly stated otherwise in a specific Codex standard.

4.1. The name of the food

- The name shall indicate the true nature of the food and normally be specific and not generic:

1. Where a name or names have been established for a food in a Codex standard, at least one of these names shall be used.
2. In other cases, the name prescribed by national legislation shall be used.
3. In the absence of any such name, either a common or usual name existing by common usage as an appropriate descriptive term which was not misleading or confusing to the consumer shall be used.
4. A "coined", "fanciful", "brand" name, or "trade mark" may be used provided it accompanies one of the names.

- There shall appear on the label either in conjunction with, or in close proximity to, the name of the food, such additional words or phrases as necessary to avoid misleading or confusing the consumer in regard to the true nature and physical condition of the food including but not limited to the type of packing medium, style, and the condition or type of treatment it has undergone; for example: dried, concentrated, reconstituted, smoked.

4.2. List of ingredients

- Except for single-ingredient foods, the label must include a list of ingredients.

1. The list of ingredients shall be headed or preceded by an appropriate title which consists of or includes the term 'ingredient'.
2. All ingredients shall be listed in descending order of ingoing weight (m/m) at the time of the manufacture of the food.
3. If a compound ingredient is made up of two or more ingredients, it can be listed in the ingredients, accompanied by a bracketed list of its components, in descending order of proportion (mass/mass). If a compound ingredient, with a specific name established in a

Codex standard or national legislation, constitutes less than 5% of the food, only the food additives serving a technological function in the finished product need to be declared.

4. The following foods and ingredients are known to cause hypersensitivity and shall always be declared (**Expert Committee on Food Additives (JECFA**).
   - ❖ Cereals containing gluten; i.e., wheat, rye, barley, oats, spelt or their hybridized strains and products of these;
   - ❖ Crustacea and products of these;
     - Eggs and egg products;
     - Fish and fish products;
     - Peanuts, soybeans and products of these;
     - Milk and milk products (lactose included);
     - Tree nuts and nut products; and
     - Sulphite in concentrations of 10 mg/kg or more.
5. Added water should be listed in the ingredients, unless it is already included as part of another ingredient such as brine, syrup, or broth in a compound food, and has been clearly stated in the ingredient list. Water or other volatile ingredients that evaporate during the manufacturing process are exempt from being declared.
6. Instead of the standard guidelines in this section, dehydrated or condensed foods meant to be reconstituted with water only can have their ingredients listed in proportion (mass/mass) based on the reconstituted product. However, a statement like "ingredients of the product when prepared following the instructions on the label" must be included.
7. Any food or food ingredient obtained through biotechnology that contains an allergen transferred from any of the products listed in Section 4 must be declared.

If it is not feasible to provide sufficient information about the presence of an allergen through labeling, the food containing the allergen should not be allowed for sale in the market.

A specific name shall be used for ingredients in the list of ingredients in accordance with the provisions set (Name of the Food). Likewise, if a broader category name would offer clearer information, the following category names can be employed (**Table 11**):

Tableau 11. Names of ingredients employed

Name of classes	**Class names**
Refined oils other than olive	'Oil' together with either the term 'vegetable' or 'animal', qualified by the term 'hydrogenated' or 'partially-hydrogenated', as appropriate
Refined fats	'Fat' together with either, the term 'vegetable' or 'animal', as appropriate.
Starches, other than chemically modified starches	'Starch'.
All species of fish where the fish constitutes an ingredient of another food and provided that the labelling and presentation of such food does not refer to a specific species of fish.	'Fish'.
All types of poultrymeat where such meat constitutes an ingredient of another food and provided that the labelling and presentation of such a food does not refer to a specific type of poultrymeat.	Poultrymeat'.
All types of cheese where the cheese or mixture of cheeses constitutes an ingredient of another food and provided that the labelling and presentation of such food does not refer to a specific type of cheese	'Cheese'
All spices and spice extracts not exceeding 2% by weight either singly or in combination in the food.	'Spice', 'spices', or 'mixed spices', as appropriate.
All herbs or parts of herbs not exceeding 2% by weight either singly or in combination in the food	'Herbs' or 'mixed herbs', as appropriate.
All types of gum preparations used in the manufacture of gum base for chewing gum.	'Gum base'.
All types of sucrose.	'Sugar'.
Anhydrous dextrose and dextrose monohydrate	'Dextrose' or 'glucose'.
All types of caseinates.	'Caseinates'
Press, expeller or refined cocoa butter.	'Cocoa butter'.
All crystallized fruit not exceeding 10% of the weight of the food.	'Crystallized fruit'.

1. Notwithstanding the provision set out in Section 1, pork fat, lard and beef fat shall always be declared by their specific names.
2. Food additives belonging to the relevant categories and listed in the permitted food additives for general food use must be labeled using the appropriate category titles, along with the specific name or recognized numerical identification mandated by national legislation.

- ❖ Acidity Regulator
- ❖ Acids
- ❖ Anticaking Agent
- ❖ Antifoaming Agent
- ❖ Antioxidant
- ❖ Bulking Agent
- ❖ Colour
- ❖ Colour Retention Agent
- ❖ Emulsifier
- ❖ Emulsifying Salt
- ❖ Firming Agent
- ❖ Flour Treatment Agent
- ❖ Flavour Enhancer
- ❖ Foaming Agent
- ❖ Gelling Agent
- ❖ Glazing Agent
- ❖ Humectant
- ❖ Preservative
- ❖ Propellant
- ❖ Raising Agent

3. The following class titles may be used for food additives falling in the respective classes and appearing in lists of food additives permitted generally for use in foods:
    - ❖ Flavour(s) and Flavouring(s)

Modified Starch(es)The expression "flavours" may be qualified by "natural", "nature identical", "artificial" or a combination of these words as appropriate.

4.3. Net contents and drained weight

1. The net contents of the product must be stated in metric units of the International System of Units (SI).

2. The net contents shall be declared in the following manner:

- for liquid foods, by volume;
- for solid foods, by weight;
- for semi-solid or viscous foods, either by weight or volume.

4. In addition to stating the net contents, food packed in a liquid medium must also include a declaration in the metric system indicating the drained weight of the food. For the purpose of this requirement, a liquid medium refers to water, aqueous solutions of sugar and salt, fruit and vegetable juices found in canned fruits and vegetables only, or vinegar, either individually or in combination.

4. 4. Name and address

The name and address of the food's manufacturer, packer, distributor, importer, exporter, or vendor must be indicated.

4. 5. Country of origin

The food's country of origin must be indicated if its absence could mislead or deceive the consumer.

If a food undergoes processing in a second country that significantly alters its characteristics, the country where the processing occurs will be considered the country of origin for labeling purposes.

4.6. Lot identification

Each container must have an embossed or permanently marked code, either in code or in clear, to identify the manufacturing factory and the lot.

4.7. Date marking and storage instructions

If not specified in a specific Codex standard, the following date marking guidelines shall be followed:

1. The “date of minimum durability” shall be declared.
2. This shall consist at least of:
    - the day and the month for products with a minimum durability of not more than three months;
    - the month and the year for products with a minimum durability of more than three months. If the month is December, it is sufficient to indicate the year.
3. The date shall be declared by the words:
    - “Best before ...” where the day is indicated;
    - “Best before end ...” in other cases.
4. The words referred to in paragraph (iii) shall be accompanied by:
    - either the date itself; or
    - a reference to where the date is given.
5. The day, month, and year must be stated in numerical sequence without any coding. However, in countries where it will not confuse consumers, the month may be indicated using letters.
6. Notwithstanding an indication of the date of minimum durability shall not be required for:

- fresh fruits and vegetables, including potatoes which have not been peeled, cut or similarly treated;
- wines, liqueur wines, sparkling wines, aromatized wines, fruit wines and sparkling fruit wines;
- beverages containing 10% or more by volume of alcohol;
- bakers' or pastry-cooks' wares which, given the nature of their content, are normally consumed within 24 hours of their manufacture;
- vinegar;
- food grade salt;
- solid sugars;
- confectionery products consisting of flavoured and/or coloured sugars;
- chewing gum.

7. In addition to the date of minimum durability, any special conditions for the storage of the food shall be declared on the label if the validity of the date depends thereon.

4.8. Instructions for use

Instructions for use, including reconstitution, where applicable, shall be included on the label, as necessary, to ensure correct utilization of the food.

5. Additional mandatory requirements

5.1. Quantitative labelling of ingredients

If a food label emphasizes the presence of specific valuable and/or characterizing ingredients or if the food description has a similar effect, the percentage of the ingredient in the product (mass/mass) at the time of manufacture must be declared.

Likewise, if a food label emphasizes the low content of specific ingredients, the percentage of the ingredient (mass/mass) in the final product must be declared.

Mentioning a specific ingredient in the name of a food does not automatically imply special emphasis. Similarly, referring to an ingredient used in small quantities solely as a flavoring in the food labeling does not by itself indicate special emphasis.

5.2. Irradiated foods

The label of a food that has undergone ionizing radiation treatment must include a written statement indicating this treatment, placed near the food's name. While the use of the international food irradiation symbol (as depicted below) is optional, if used, it should be positioned close to the food's name.

Figure 14. International Food Irradiation Symbol

If an irradiated product is utilized as an ingredient in another food, this must be clearly stated in the list of ingredients.

When a single-ingredient product is created from a raw material that has undergone irradiation, the product's label must include a statement indicating this treatment.

6. Optional labelling

Information or pictorial representations can be displayed on labels, whether written, printed, or graphic, as long as they do not contradict the compulsory regulations outlined in this standard and the guidelines regarding claims and deception as specified in Section 3 - General Principles.

If grade designations are used, they shall be readily understandable and not be misleading or deceptive in any way.

7. Presentation of mandatory information

7.1 General

Labels on prepackaged foods must be affixed securely to prevent detachment from the container.

Any statements mandated by this standard or other Codex standards must be clear, prominent, permanent, and easily readable by consumers under normal purchase and usage conditions.

If the container is wrapped, the wrapper should display the required information, or if the label is on the container, it should be visible through the outer wrapper without being obscured by it.

The food's name and net contents must be prominently placed within the same field of vision for consumers.

8.2. Language

If the language on the original label is not understandable to the intended consumer, a supplementary label containing the necessary information in the required language may be used instead of relabeling the entire package.

In either case, whether through relabeling or a supplementary label, the mandatory information provided must completely and accurately reflect the content of the original label.

II. Nutrition labelling

1. Principles for nutrition labelling

a. Nutrient declaration

The information provided should offer consumers a comprehensive overview of the nutrients presents in the food, emphasizing their nutritional significance. However, it should not imply precise quantitative knowledge about individuals' dietary needs for maintaining good health. Instead, the goal is to convey an understanding of the nutrient quantities present in the product. Providing an exact quantitative breakdown for individual needs is not feasible, as there is no practical method for utilizing such information in food labeling.

b. Supplementary nutrition information

The supplementary nutrition information provided can differ significantly from one country to another and even within a country, depending on the educational policies of the nation and the specific requirements of the target population groups.

c. Nutrition labelling

Nutrition labelling should not suggest that a labeled food product inherently possesses nutritional benefits compared to a non-labeled food product.

2. Definitions

Nutrition labelling is a description intended to inform the consumer of nutritional properties of a food.

Nutrition labelling consists of two components:

(a) nutrient declaration.

(b) supplementary nutrition information.

A nutrition declaration refers to a standardized statement detailing the nutrient content of a food product.

A nutrition claim, on the other hand, is any statement that suggests or implies specific nutritional qualities of a food, such as energy value, protein, fat, carbohydrates, vitamins, and minerals. It does not include:

(a) Listing substances in the ingredients.

(b) Including nutrients as a mandatory part of nutrition labeling.

(c) Quantitative or qualitative declarations of specific nutrients or ingredients on the label as mandated by national legislation.

Nutrient: means any substance normally consumed as a constituent of food:

(a) which provides energy; or

(b) which is needed for growth, development and maintenance of life; or

(c) a deficit of which will cause characteristic bio-chemical or physiological changes to occur.

Sugars: means all mono-saccharides and di-saccharides present in food.

Dietary fibre: means edible plant and animal material not hydrolysed by the endogenous enzymes of the human digestive tract as determined by the agreed upon method.

Polyunsaturated fatty acids: means fatty acids with cis-cis methylene interrupted double bonds.

3. Nutrient declaration

3.1. Application of nutrient declaration

Nutrient declaration should be mandatory for foods for which nutrition claims,

Nutrient declaration should be voluntary for all other foods.

3.2. Listing of nutrients

Where nutrient declaration is applied, the declaration of the following should be mandatory:

Where nutrient declaration is applied, the declaration of the following should be mandatory

- Energy value;
- The amounts of protein, available carbohydrate (i.e., carbohydrate excluding dietary fibre) and fat;
- 3.2.1.3 The amount of any other nutrient for which a nutrition claim is made;
- 3.2.1.4 The amount of any other nutrient considered to be relevant for maintaining a good nutritional status, as required by national legislation.

Where a claim is made regarding the amount and/or the type of carbohydrate, the amount of total sugars should be listed in addition to the requirements. The amounts of starch and/or other carbohydrate constituent(s) may also be listed. Where a claim is made regarding the dietary fibre content, the amount of dietary fibre should be declared.

Where a claim is made regarding the amount and/or type of fatty acids, the amounts of saturated fatty acids and of polyunsaturated fatty acids should be declared.

In addition to the mandatory declaration vitamins and minerals may be listed in accordance with the following criteria:

- Only vitamins and minerals for which recommended intakes have been established and/or which are of nutritional importance in the country concerned should also be declared.

- When nutrient declaration is applied, only those vitamins and minerals which are present in significant amounts should be listed.
- In the case where a product is subject to labelling requirements of a Codex standard, the provisions for nutrient declaration set out in that standard should take precedence over but not conflict with the provisions.

3.3. Presentation of nutrient content

- ✓ The nutrient content declaration must be numerical, but it does not exclude the use of additional presentation methods.
- ✓ Information regarding energy value must be expressed in both kJ (kilojoules) and kcal (kilocalories) per 100 g or 100 ml, or per package if it contains only a single portion. Alternatively, it can be given per serving size as specified on the label or per portion, provided that the number of portions within the package is clearly stated.
- ✓ Details about the protein, carbohydrate, and fat content in the food product must be expressed in grams (g) per 100 g or per 100 ml, or per package if it consists of a single portion. Additionally, this information can also be presented per serving size as specified on the label, or per portion, as long as the number of portions within the package is clearly indicated.
- ✓ Numeric details regarding vitamins and minerals must be expressed in metric units and/or as a percentage of the Nutrient Reference Value per 100 g, 100 ml, or per package if it comprises only a single portion. Moreover, this information can also be presented per serving size as specified on the label or per portion, as long as the number of portions within the package is clearly specified.
- ✓ Furthermore, information about protein content can also be expressed as a percentage of the Nutrient Reference Value.

The following Nutrient Reference Values should be used for labelling purposes in the interests of international standardization and harmonization:

Protein	(g)	50
Vitamin A	(µg)	800 [2]
Vitamin D	(µg)	5 [3]
Vitamin C	(mg)	60
Thiamin	(mg)	1.4
Riboflavin	(mg)	1.6
Niacin	(mg)	18 [3]
Vitamin B_6	(mg)	2
Folic acid	(µg)	200
Vitamin B_{12}	(µg)	1
Calcium	(mg)	800
Magnesium	(mg)	300
Iron	(mg)	14
Zinc	(mg)	15
Iodine	(µg)	150 [3]
Copper	Value to be established	

The presence of available carbohydrates should be declared on the label as "carbohydrates". Where the type of carbohydrate is declared, this declaration should follow immediately the declaration of the total carbohydrate content in the following format :

"Carbohydrate ... g, of which sugars ... g".

This may be followed by the following: "x" ... g

where "x" represents the specific name of any other carbohydrate constituent.

3.4. Supplementary nutrition information

- ✓ Supplementary nutrition information is designed to enhance consumers' awareness of the nutritional content of their food and aid in interpreting the nutrient declaration. There are various methods available for presenting such information on food labels.
- ✓ The utilization of supplementary nutrition information on food labels is optional. It should be provided in addition to, and not as a substitute for, the nutrient declaration. However, exceptions can be made for target populations with high illiteracy rates and/or limited

nutrition knowledge. In such cases, food group symbols or other visual representations like pictorial or color presentations may be used without the nutrient declaration.

- ✓ When supplementary nutrition information is included on labels, it should be accompanied by consumer education programs. These programs are essential to enhance consumer understanding and encourage the effective use of the information provided.

Tableau 12. Conditions for nutrient contents

COMPONENT	CLAIM	CONDITIONS NOT MORE THAN
Energy	Low	40 kcal (170 kJ) per 100 g (solids) or 20 kcal (80 kJ) per 100 ml (liquids)
	Free	4 kcal per 100 ml (liquids)
Fat	Low	3 g per 100 g (solids) 1.5 g per 100 ml (liquids)
	Free	0.5 g per 100 g (solids) or 100 ml (liquids)
Saturated Fat	Low[1]	1.5 g per 100 g (solids) 0.75 g per 100 ml (liquids) and 10% of energy
	Free	0.1 g per 100 g (solids) 0.1 g per 100 ml (liquids)
Cholesterol	Low[1]	0.02 g per 100 g (solids) 0.01 g per 100 ml (liquids)
	Free	0.005 g per 100 g (solids) 0.005 g per 100 ml (solids) and, for both claims, less than: 1.5 g saturated fat per 100 g (solids) 0.75 g saturated fat per 100 ml (liquids) and 10% of energy of saturated fat
Sugars	Free	0.5 g per 100 g (solids) 0.5 g per 100 ml (liquids)
Sodium	Low	0.12 g per 100 g
	Very Low	0.04 g per 100 g
	Free	0.005 g per 100g
Protein	Source	10% of NRV per 100 g (solids) 5% of NRV per 100 ml (liquids) or 5% of NRV per 100 kcal (12% of NRV per 1 MJ) or 10% of NRV per serving
	High	2 times the values for "source"
Vitamins and Minerals	Source	15% of NRV per 100 g (solids) 7.5% of NRV per100 ml (liquids) or 5% of NRV per 100 kcal (12% of NRV per 1 MJ) or 15% of NRV per serving
	High	2 times the value for "source"

General guidelines for use of the term "HALAL"

1. Interlocution

The *Codex Alimentarius* Commission acknowledges that slight variations in the interpretation of lawful and unlawful animals and the slaughter process exist based on different Islamic Schools of Thought. Therefore, these overarching guidelines are open to interpretation by the relevant authorities in the importing nations. Nonetheless, certificates issued by the religious authorities of the exporting country should be generally accepted by the importing country, unless specific justifications for alternative requirements are provided.

2. Definition

Halal Food means food permitted under the Islamic Law and should fulfil the following conditions:

1. does not consist of or contain anything which is considered to be unlawful according to Islamic Law;
2. has not been prepared, processed, transported or stored using any appliance or facility that was not free from anything unlawful according to Islamic Law; and
3. has not in the course of preparation, processing, transportation or storage been in direct contact with any food that fails to satisfy.

Halal food can be prepared, processed or stored in different sections or lines within the same premises where non-halal foods are produced, provided that necessary measures are taken to prevent any contact between halal and non-halal foods;

Halal food can be prepared, processed, transported or stored using facilities which have been previously used for non-halal foods provided that proper cleaning procedures, according to Islamic requirements, have been observed.

3. Criteria for use of the term "HALAL"

3.1. Lawful food

The term halal may be used for foods which are considered lawful. Under the Islamic Law, all sources of food are lawful except the following sources, including their products and derivatives which are considered unlawful:

3.1.1 Food of Animal Origin

(a) Pigs and boars.

(b) Dogs, snakes and monkeys.

(c) Carnivorous animals with claws and fangs such as lions, tigers, bears.

(d) Birds of prey with claws such as eagles, vultures, and other similar birds.

(e) Pests such as rats, centipedes, scorpions and other similar animals.

(f) Animals forbidden to be killed in Islam i.e., ants, bees and woodpecker birds.

(g) Animals which are considered repulsive generally like lice, flies, maggots.

(h) Animals that live both on land and in water such as frogs, crocodiles.

(i) Mules and domestic donkeys.

(j) All poisonous and hazardous aquatic animals.

(k) Any other animals not slaughtered according to Islamic Law.

(l) Blood.

3.1.2 Food of Plant Origin

Intoxicating and hazardous plants except where the toxin or hazard can be eliminated during processing.

3.1.3 Drink

(a) Alcoholic drinks.

(b) All forms of intoxicating and hazardous drinks.

3.2 Slaughtering

All lawful land animals should be slaughtered in compliance with the rules laid down in the Codex Recommended Code of Hygienic Practice for Fresh Meat and the following requirements:

- The person should be a Muslim who is mentally sound and knowledgeable of the Islamic slaughtering procedures.
- The animal to be slaughtered should be lawful according to Islamic law.
- The animal to be slaughtered should be alive or deemed to be alive at the time of slaughtering.
- The phrase "Bismillah" (In the Name of Allah) should be invoked immediately before the slaughter of each animal.
- The slaughtering device should be sharp and should not be lifted off the animal during the slaughter act.
- The slaughter act should sever the trachea, oesophagus and main arteries and veins of the neck region.

3.3 Preparation, processing, packaging, transportation and storage

All food should be prepared, processed, packaged, transported and stored in such a manner that it complies following the Codex General Principles on Food Hygiene and other relevant Codex Standards.

4. Additional labelling requirements

- When a claim is made that a food is halal, the word halal or equivalent terms should appear on the label.

- In accordance with the Codex General Guidelines on Claims, claims on halal should not be used in ways which could give rise to doubt about the safety of similar food or claims that halal foods are nutritionally superior to, or healthier than, other foods.

5. Ministry's decree September 2023.

The Ministry of Commerce and Export Promotion informs all economic operators that, in accordance with the conclusions of the National Committee for Monitoring the Certification and Labeling of "halal" for the relevant food products, established by the the interministerial decree of 9 Ramadan 1437 corresponding to June 14, 2016, establishing the conditions and procedures for affixing the "halal" label on relevant food products, and specifying the list of imported food products subject to the obligation of affixing the "halal" label - halal certification - is as follows:

- ✓ Meats and products of animal origin, including meat products;
- ✓ Animal oils and fats;
- ✓ Confectionery, including chocolates;
- ✓ Cakes and biscuits;
- ✓ Food additives of animal origin and/or composed of elements that may not be halal due to their methods of acquisition, pre-packaged and intended for resale in their original state or intended for the food industry;
- ✓ Milk derivatives, including caseinates;
- ✓ All cheeses intended for processing or the food industry;
- ✓ Infant formulas and follow-on formulas;
- ✓ Rennets.

Chapter V.
Hazards Analysis and Critical Control Points (HACCP) system

Chapter V. Hazards Analysis and Critical Control Points (HACCP) system

1. Introduction

Hazard Analysis by Critical Control Point (HACCP) is a structured method for recognizing, evaluating, and managing potential risks. Originally created by the Pillsbury Company in the 1960s, HACCP was designed as a practical strategy to ensure the safety of food products intended for space travel (**APHA, 1971; Pillsbury Company, 1973**).

The initial research, carried out in partnership with the National Aeronautics and Space Administration (NASA), the United States Army Laboratories, and the United States Air Force Space Laboratory Project Group, determined that traditional endpoint food testing was ineffective in guaranteeing food safety. This was due to the following reasons:

- Significant proportions of a foodstuff have to be sub-sampled for analysis to ensure representivity.
- Food safety is only ensured with regards to tested hazards.
- Current food safety testing procedures are likely to be expensive, time-consuming, difficult to interpret and destructive.
- Control of hazards is reactive.
- Responsibility for food safety is focused upon a relatively small component of the workforce: quality assurance and control personnel.
- Food safety is only assured at the point of testing (**Ropkins and Beck, 2000**).

Consequently, HACCP was developed as a proactive alternative to end-point testing. The original Pillsbury HACCP procedure (**Pillsbury Company, 1973)** contained three components:

1. The identification and assessment of all hazards associated with the final foodstuff.
2. The identification of the steps or stages within food production at which these hazards may be controlled, reduced or eliminated: The Critical Control Points (CCPs).
3. The implementation of monitoring procedures at these CCPs.

Food companies, affiliated organizations in the food industry, and government bodies have adopted varying interpretations of HACCP. As a result, HACCP has adapted to address the distinct requirements of stakeholders, including food handlers (such as producers, manufacturers, and distributors), regulatory authorities, and consumers (**Savage, 1995**). However, despite this, the three components listed above remain inherent in all contemporary HACCP procedures. This combination of practical (prevention-orientated) primary components and a flexible approach to their implementation has been identified as HACCP's greatest attribute. It allows HACCP to remain relevant, efficient and effective, despite the introduction of new food technologies (**Ropkins and Beck, 2000**).

2. HACCP and food safety management systems (FSMS)

Effective HACCP application is crucial to the management of food safety; however, it is important to understand that HACCP is just one part of a successful FSMS. Often businesses and stakeholders talk with confidence of having "done HACCP" or being "HACCP Checked" or "HACCP Certified," and therefore everything must be OK. In reality the HACCP part of the FSMS is, arguably, the most important because this is where decisions are taken about how to manage significant food safety hazards. Nevertheless, the FSMS will only be fully effective if all the required elements are carefully designed, developed, implemented, and maintained within the food operation (**Wallace and Mortimore, 2016**)

Figure 15, shows the elements of the modern day FSMS. We recognize that each of these elements requires an interdependency for a robust food safety management program.

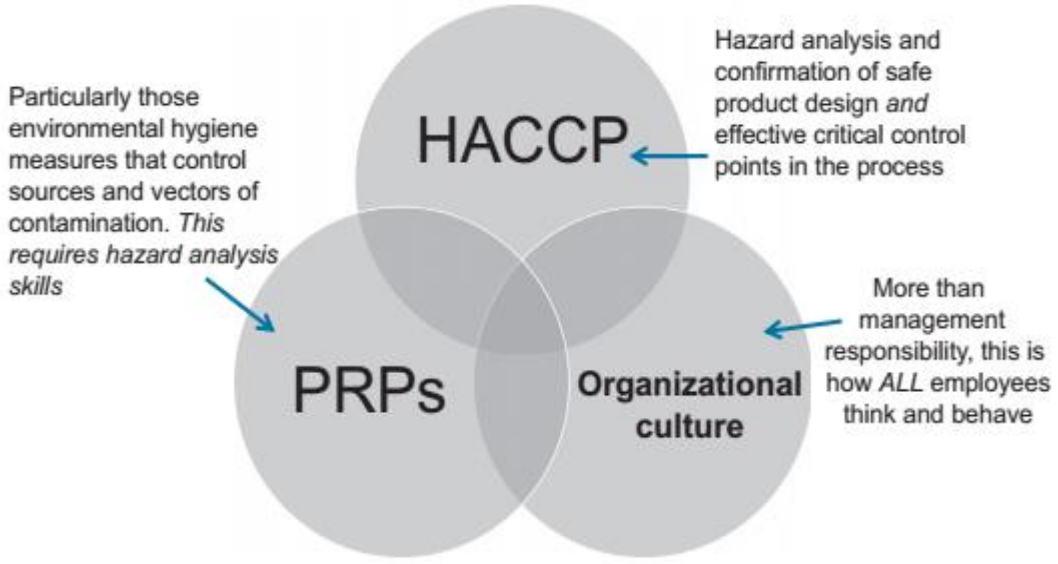

Figure 15. Elements of the modern-day food safety management system (**Wallace and Mortimore, 2016**).

3. Prerequisite Programs

These are the practices and conditions needed prior to and during the implementation of HACCP and which are essential to food safety. Prerequisite Programs (PRPs) provide a hygienic foundation for the HACCP system by enabling environmental conditions that are favorable for the production of safe food. Like the HACCP system, there is international agreement on the general principles required (**Codex, 2009b**) and, although Codex does not itself use the term PRPs, the essential characteristics of PRPs are laid out under the following headings for application to food businesses:

- Design and Facilities;
- Control of Operation;
- Maintenance and Sanitation;
- Personal Hygiene;
- Transportation;
- Product Information and Consumer Awareness;
- Training.

In order to develop effective PRPs, personnel must have knowledge and experience of current best practice in food hygiene management, as well as an appreciation of the key issues to be managed in their operation, for example, likely pest issues or constraints from building fabric. Many of the chapters in this book will be invaluable when considering how to design effective PRPs in support of HACCP (**Wallace and Mortimore, 2016**).

3.1. Pre-requests definition

According to the definition provided by ISO 22000, prerequisite programs for food safety encompass a set of "basic conditions and activities necessary to maintain, throughout the food chain, a hygienic environment suitable for the production, handling, and provision of safe finished products and safe foodstuffs for human consumption." It is therefore a tool to ensure food safety preventively. For several decades, stakeholders in the agri-food sector, in collaboration with health authorities and scientists, have developed an arsenal of tools and practices ensuring optimal food safety.

3.2. Cleaning and disinfection programs

Cleaning and disinfection programs must be established and validated by the organization to ensure that all parts of the establishment and equipment are cleaned and/or disinfected according to a defined schedule, including the of cleaning equipment.

Cleaning and/or cleaning disinfection programs must specify at a minimum:

a) the areas, elements of equipment, and utensils to be cleaned and/or disinfected;

b) the individuals responsible for the specified tasks;

c) the method and frequency of cleaning/disinfection;

d) monitoring and verification arrangements;

e) inspections after cleaning;

f) inspections before resuming operations.

3.3. Pest control

A staff member of the establishment must be appointed to manage pest control activities and/or enlist the services of designated expert subcontractors. Pest control programs must be documented and should identify targeted pests. They should also include plans, methods, schedules, control procedures, and, if necessary, training requirements.

The programs must include a list of chemicals whose usage is approved in specified areas of the establishment.

a) Specific pest control methods to be implemented.

b) Specific areas of the establishment affected by pest control activities.

c) Products or substances used in the pest control process.

d) Frequencies of application for pest control methods.

e) Clear responsibilities of personnel in charge of managing pest control activities.

f) Monitoring and evaluation protocols to assess the effectiveness of pest control programs.

g) Corrective actions to be taken in case of pest identification or failure of control methods.

h) Recording and documentation procedures for pest control activities.

3.4. Personnel hygiene

3.4.1. Personnel hygiene and facilities

Personnel hygiene facilities shall be available to maintain the degree of personal hygiene required by the organization. The facilities shall be located close to the points where hygiene requirements apply and shall be clearly designated.

According to their size and complexity, organizations shall:

a) Provide, in appropriate numbers, facilities for washing, drying, and, if necessary, hygienically disinfecting hands (including sinks, hot and cold or temperature-regulated water supply, and soap and/or antiseptic);

b) Have dedicated hand-washing sinks equipped with non-manual faucets, separate from sinks used for food-related purposes and equipment washing stations;

c) Have an adequate number of hygienically designed toilets, all equipped with washing, drying, and, if necessary, disinfection facilities;

d) Provide hygiene facilities for employees that do not open directly into production, packaging, or storage areas;

e) Have suitable facilities for changing employee attire;

f) Provide changing facilities situated to allow food-handling personnel to enter the production area while minimizing the risk of soiling their work attire.

3.4.2. Health Status

Unless there are specific legal provisions in the country where the organization operates, employees must undergo a medical examination before being hired for an activity that involves contact with food items (including catering services), unless a hazard assessment or documented medical evaluation indicates otherwise.

Additional medical examinations, when permitted, should be conducted at intervals defined by the organization.

3.4.3. Personal Hygiene

Personnel present in food production areas must wash and, if necessary, disinfect their hands:

a) before commencing any food handling activity;

b) immediately after using toilets or blowing their nose;

c) immediately after handling any potentially contaminated material.

Personnel should refrain from sneezing or coughing over materials or products. Spitting (expectorating) must be prohibited. Hand nails should be clean and short.

3.4.4. Personnel Behavior

A documented policy should outline the expected behaviors of staff in manufacturing, packaging, and storage areas. This policy should, at a minimum, cover:

a) permission to smoke, eat, or chew in designated areas;

b) control measures to minimize risks related to the wearing of authorized jewelry, such as those that may be worn by staff in manufacturing and storage areas for religious, ethnic, medical, and cultural reasons;

c) permissions to use personal items, such as cigarettes and medications, in designated areas;

d) prohibition of nail polish, false nails, and false eyelashes;

e) prohibition of wearing writing tools behind the ears;

f) maintenance of personal lockers to ensure they are free of litter and dirty clothing;

g) prohibition of storing tools and equipment intended to come into contact with the product in personal lockers.

4. HACCP Advantage

Although the adoption of HACCP systems worldwide is primarily attributed to the increased protection, it offers to consumers in terms of food safety, the successful implementation of an HACCP system carries other benefits for the food industry as a whole and for your business.

1. **Sensibilization increases of food safety**

Food safety is the responsibility of all stakeholders in the food supply system. By developing and implementing an HACCP system, your staff will become more aware of food safety and its role

in maintaining and contributing to it. This awareness enables employees to take the production of safe products more seriously.

2. **Improved confidence of buyers and consumers**

More and more buyers are requiring their suppliers to adopt an HACCP system. Food processing companies that have done so assure buyers and consumers that their facility provides them with safe food products.

3. **Maintaining or improving market access**

Market forces continue to promote awareness of food safety and the adoption of HACCP systems throughout the food industry. As food safety systems, especially HACCP systems, become more widespread, food processing companies that do not adopt them find it increasingly challenging to access markets. In many cases, buyer requirements compel companies to implement HACCP to maintain or gain market share, including access to previously inaccessible markets. HACCP can also enable a company to regain access to a market it had lost. Considering the economic stakes, implementing HACCP could prove essential.

4. **Protection against civil liability**

Implementing an HACCP system could partially protect your establishment against civil liability and reduce your insurance premiums.

5. **Reduction in operating expenses**

To develop and implement HACCP, it is necessary to examine and analyze the entire manufacturing process and document procedures. This process often uncovers opportunities to streamline operating expenses. For instance, developing a sanitation program might reveal that chemicals are being used in excessively high concentrations, and reducing these concentrations could lower sanitation costs.

6. **Effective monitoring**

Likewise, implementing HACCP could enable your company to conduct effective monitoring. Indeed, the cost associated with implementing HACCP can be outweighed by its benefits. Regular activities such as product and process monitoring, staff training, and procedure review allow your company to rigorously govern both the facility and its products. You may discover that certain aspects of your processes could be made more efficient and productive.

7. **Improvement in product quality and consistency**

Implementing an HACCP system could indirectly enhance product quality. Procedures aimed at reducing the presence and growth of pathogenic microorganisms may have a similar effect on spoilage microorganisms, thereby increasing the shelf life of products. Furthermore, standardizing procedures will improve product consistency.

8. Reduction of waste

The preventive nature of HACCP enables the company to control its costs by minimizing the need for reworking or discarding products and focusing resources on aspects deemed essential for producing safe food products. Many issues are resolved before they escalate and before products are shipped; you won't have to rely solely on the results of finished product analysis. Through the regular monitoring integrated into the HACCP system, you can detect issues earlier and reduce costs associated with waste

5. HACCP plan

Each HACCP plan is unique to your establishment and the product groups for which it was designed. The number of plans you will need in your establishment depends on the types of products you manufacture and the processes you use. Quite often, it is possible to group products into categories and develop an HACCP plan for each of them.

If you manufacture similar products using similar processing methods and if the finished products have similar risks, you can group them under a single HACCP plan. However, if you produce different products or if different food safety risks are associated with the manufacturing process or the final product, these products should be grouped into separate HACCP plans.

For example, if you manufacture five different types of meatloaf, you can group them into a single HACCP plan if they all have similar food safety risks. However, if you produce cooked meatloaf, dry-cured pepperoni, and boneless raw chicken breasts, you would need a separate HACCP plan for each of these products because they are not manufactured using the same process and have different food safety risks (**Jenner et al., 2005**)

6. HACCP procedure

HACCP serves as a tool for creating, implementing, and managing effective safety assurance protocols rather than being a safety assurance procedure in itself. Its initial purpose was to assist individual food companies, including food producers, manufacturers, distributors, and retailers, in crafting tailored safety assurance protocols tailored to their specific requirements. The nature and seriousness of hazards can significantly differ from case to case, considering factors like location, food type, ingredients, and production lines. Therefore, this approach proves more effective than enforcing uniformly predefined safety assurance procedures across all sectors of the food industry (**Ropkins and Beck, 2000**). Consequently, most published HACCP guidelines focus upon the implementation process and although, HACCP documentation is available from many sources, there is a surprising amount of consistency in the approaches adopted and the safety recommendations made. For example, the International Commission on Microbiological Specifications for Foods (**ICMSF, 1988**), the National Advisory Committee on Microbiological Criteria for Foods (**NACMCF, 1989; 1992**), the

Codex Alimentarius Commission (**CAC, 1993**) and the International Life Science Institute (**ILSI, 1993**) HACCP guidelines all recommend very similar implementation protocols.

According to the World Health Organization (1997), there are seven basic principles that should be followed for HACCP implementation:

1. identifying potential hazards;
2. determining CCPs according to the hazards that were determined (using the decision tree);
3. establishing critical limits for the preventive measures associated with each CCP;
4. determining a monitoring routine as a function of the critical limits;
5. establishing corrective measures to be implemented in cases of noncompliance with critical limits;
6. establishing an effective record system for the program; establishing a verification system for the ongoing HACCP system.

The table 1 shows the principles and their objectives in detail.

The logic system for the application of HACCP, according to the Codex Alimentarius (**Food and Agriculture Organization, 1997**), has 12 steps that start before these seven principles and involve them as the implementation of the system progresses, as follows:

(1) assembly of HACCP team;

(2) description of the product;

(3) identification of the intended use;

(4) building of the flow diagram;

(5) onsite confirmation of the flow diagram;

(6) principle 1: listing of the potential analysis; conduction of the hazard analysis; determination of control measures;

(7) principle 2: determination of CCPs;

(8) principle 3: establishing critical limits for each CCP;

(9) principle 4: establishing monitoring systems for each CCP;

(10) principle 5: establishing corrective actions;

(11) principle 6: establishing verification procedures;

(12) principle 7: establishing documentation and record-keeping procedures;

Tableau 13. Description of the HACCP Principles and Their Respective Objectives (**de Oliveira et al., 2016**)

Principle	Objective
1. Analyzing hazards and preventive measures	Defining: which hazards exist (biological, chemical and physical)/how to conduct the hazard analysis/how to identify significant hazards/which preventive measures exist/how to identify preventive measures.
2. Identifying critical control points	Identifying and characterizing CCPs (considering the direct relationship between the significant hazard and the CCP)/making this decision by either using the decision tree or answering the questions.
3. Establishing critical limits for the preventive measure associated with each CCP	Establishing how to define a critical limit/quantifying the critical limit as a function of the CCP/obtaining information on the critical limit.
4. Establishing the need for monitoring the CCP and the procedures to use the results, to adjust the process and to maintain control	Defining: what monitoring is, what to monitor and why/which methods and equipment are used to monitor the critical limit/the frequency of monitoring and the responsible person for monitoring procedures.
5. Implementing corrective actions in cases of noncompliance with a critical limits	Defining the corrective action/establishing the procedure for the corrective action/keeping adequate records of corrective actions.
6. Establishing and maintaining records of HACCP procedures.	Determining which records are necessary to complete the HACCP plan/when to monitor the information that was recorded/how records are to be used.
7. Establishing procedures to validate the correct functioning of the HACCP system.	Defining the validation form/validation functions in the HACCP plan.

7. HACCP steps

Step 1. HACCP team

The initial steps of HACCP implementation involve an audit process, during which data is gathered for the exercise (**Mayes and Kilsby, 1989; Sperber, 1996**). HACCP implementation is usually a team exercise as no individual is likely to have all the practical, technical, theoretical and managerial expertise required. The HACCP team that is chosen should have access to all pertinent information and should possess the diverse range of expertise needed to identify all hazards, Critical Control Points (CCPs), and critical limits associated with the product and/or process being evaluated. A typical team might

comprise professionals such as a chemist, engineer, food technologist, microbiologist, production manager, quality assurance manager, and others with relevant knowledge and skills (**CAC, 1993; ILSI, 1993**). The HACCP team (**Table 14**) assembles a comprehensive description of the food product under scrutiny, which includes the identification of all ingredients, processing stages, handling methods, and other activities associated with its manufacturing. Additionally, the team should also recognize all possible (reasonable) ways in which the end-user or consumer might utilize the product (**CAC, 1993**).

Tableau 14. HACCP Team constitution (**Boutou, 2008**)

HACCP Step	**Food Safety**	**Resources/Means**	**Documentary System**
Forming the HACCP Team	Training, Related skills: - Basic microbiology - Food hygiene - Good hygiene practices - Good manufacturing practices - HACCP method	Pluridisciplinary: - Representative of the organization; - Representative of the management (mandate); - Demonstrated competencies; - Knowledge of the HACCP method (missions, principles, means); - Team facilitator; - Technical secretary. - Functional and non-hierarchical structure of the project team. - Project planning with deadlines. - Scope of the HACCP study. - Specific training for team members in the HACCP method.	Mission letter from management. - Operating charter: - Definition of the study to be conducted. - Meeting frequency. - Responsibilities (facilitator, decision-maker, and secretary). - Hazards considered (biological, chemical, physical, or other). - Communication plan (upward and downward). - Measurement of goal achievement (realistic and time-limited objectives). - Job position descriptions. Priority action sheet.

The essential expertise within the HACCP team includes:

- ❖ Understanding of the process operations, ingredients, and products on site;
- ❖ Knowledge and experience of the equipment, how it works to achieve process conditions, and the likely failure modes;
- ❖ Understanding of the likely hazards and appropriate control mechanisms, including product design safety criteria, process controls, including how to validate all the necessary control requirements;
- ❖ Knowledge and experience of HACCP principle application.

Step 2. Describe Product/Process

This step considers information both about the product(s) and the process and helps HACCP team members to understand the background to the operations that they are about to study. Normally the information is recorded formally and the resulting document then becomes a historical point of reference to the situation when the HACCP plan was developed. It forms a useful introduction to the HACCP plan and can also be used as a training tool for new personnel and briefing aid for internal or third-party auditors or regulatory inspectors.

The product/process description should include:

- ✓ Main ingredient groups to be used or "work-in-progress" (WIP) inputs to process modules;
- ✓ Main processes and how materials are prepared/handled;
- ✓ Production environment and equipment layout;
- ✓ Hazard types to be considered, if known;
- ✓ Key control measures available through formulation, processes, and prerequisites;
- ✓ Packaging/wrapping if appropriate to scope of study;
- ✓ Safe product design characteristics.

At the product/process description stage, it is also useful to add a description of the intended structure of the HACCP plan, for example, whether there is one HACCP plan spanning the entire process from ingredients to finished products or whether a modular approach is being used, which can be further elaborated at the process flow diagram stage. In foodservice operations it is also normal practice to group all the different menu/food items into like process groups at this stage, as this will help in developing process flow diagrams (**Wallace and Mortimore, 2016**).

Step 3. Identify the intended use for the product

The intended use, reasonably anticipated handling conditions of the finished product, and reasonably foreseeable misuse or erroneous use must be taken into consideration and documented as necessary for conducting the hazard analysis. User groups, and when necessary, consumer groups, must be identified for each product category, and consumer groups known to be particularly vulnerable to food safety hazards must be considered.

The information regarding the intended use is necessary to assist in identifying appropriate acceptable levels of hazards and selecting control measures combinations that achieve these levels. All 'normal' uses of the product must be considered, including:

- ✓ Storage temperature;
- ✓ Heat treatment (cooking or reheating);
- ✓ Product shelf life (Best Before Date or Use By Date);
- ✓ Product usage instructions.

The intended use of the product can be provided on a specific form (**Table 15**)

Tableau 15. The intended use of the product (**Boutou, 2008**)

<table>
<tr><td>Product Name:
Maximum Shelf Life :
Intended Consumer Usage Period:</td><td colspan="2">…….
……
…….</td></tr>
<tr><td colspan="3">Usage Guidelines:
What's written on the packaging: Recommended Storage Temperature, Cooking Time</td></tr>
<tr><td colspan="3">Storage Conditions:
Storage guidelines by distributors: Time, Temperature, Locations...
Storage practices by consumers: Observed practices</td></tr>
<tr><td colspan="3">Predicted Usage:
Results from studies, possible and observed deviations from optimal usage conditions (Temperature, Time), and potential impact on food safety. Changes in the product during these deviations (product intended to be cooked and consumed raw, etc.).
For example: Consumed over several occasions without refrigeration, despite usage guidelines recommending refrigeration...</td></tr>
<tr><td colspan="3">Population Concerned:
Can the product be consumed by sensitive population groups?
Which groups are these, and what hazards should be especially considered during the risk analysis stage?</td></tr>
<tr><td>Prepared by: ……</td><td>Date: …..</td><td>Signature: ……..</td></tr>
<tr><td>Approved by: …..</td><td>Date: ……</td><td>Signature: ……</td></tr>
</table>

Step 4. Flow diagram

The main objective of a flow diagram is to enable the identification of potential occurrences, introductions, or increases in hazard levels that may not be identified during the other initial stages (**Boutou, 2008**).

Subsequently, a flow diagram of the production process being assessed should be created. This flow diagram serves to enhance the accessibility of documentation and simplifies the management and comprehension of the HACCP procedure, once implemented (**Havelaar, 1994; Bovee et al., 1997**). The flow diagram should be meticulously cross-referenced with the actual food production process, verifying each stage on-site, under various operational conditions, and throughout all operating hours to guarantee its accuracy and representativity (**Bovee et al., 1997; Van Schothorst, and Kleiss, 1994**). If any inconsistencies are identified during this comparison, the flow diagram should be adjusted accordingly (**CAC, 1993**).

The diagrams must be clear, precise, and sufficiently detailed. The diagrams should, if applicable, include the following elements:

a. The sequence and interaction of all operational steps;

b. Outsourced processes and subcontracted work;

c. The point of entry for raw materials, ingredients, and semi-finished products into the production flow;

d. Effective points of restart and recycling;

e. Points of exit or disposal for finished products, intermediate products, by-products, and waste."

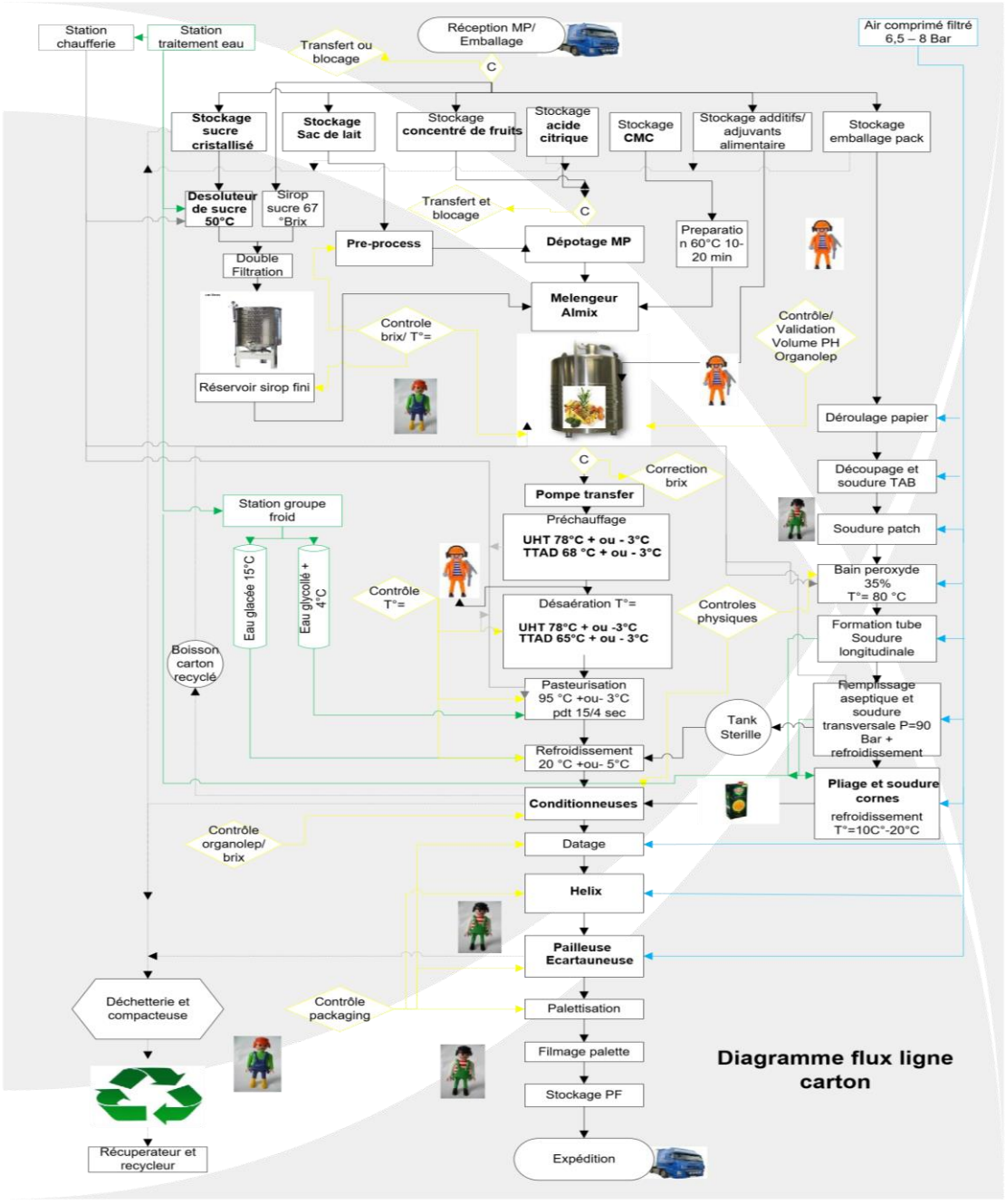

Figure 16. Flow diagram of juice product

Step 5. Confirm the manufacturing diagram

Based on the documents created (process and flow diagrams), the HACCP team must confirm all this information on-site. This must be done:

- On-site;
- For each step identified in the diagram;
- During operating hours (including night shifts for teams working in shifts, for example).

For this verification, it is necessary to follow the product's flow: from the reception of raw materials and ingredients to the shipment of the finished product. This verification is to be carried out with the entire team. It is also an opportunity to:

- ✓ Review the record-keeping system: its existence, accessibility for the concerned personnel, the equipment used, and the calibration of measuring devices;
- ✓ Test how operators understand and implement procedures and other operating methods, including monitoring and recording documents;
- ✓ Review the implementation of prerequisite programs (good hygiene practices).

Observing the product realization steps should be conducted simultaneously with interviews with supervisors and hierarchical managers. Finally, it is an opportunity to correct any errors made during the construction of the diagram or any deviations from the collected information. This verification allows addressing the discrepancies between what is believed to be done and what is actually being done.

Step 6. Hazard analysis

Within HACCP, hazard analysis serves the purpose of identifying hazards. It can be used either to assess hazards individually, assigning a score relative to a maximum safe score, or to prioritize hazards by scoring them individually and subsequently ranking them to select the most significant hazards for priority consideration. Various hazard analysis procedures have been employed, including hazard characterization, hazard assessment, semi-quantitative risk analysis, and quantitative risk analysis. The most basic form of hazard analysis is a fundamental hazard characterization, such as the NACMCF method (**NACMCF, 1989**) and its subsequent adaptations for chemical hazards. Under this approach, each ingredient and each form in which the final food product is provided to the consumer (e.g., fresh, refrigerated, frozen, or canned) is assigned specific risk characteristics (**Ropkins and Beck, 2000**):

a. Intended for 'at-risk' consumer group, e.g., infants, the elderly, the infirm or immuno-compromised individuals.

b. Ingredients are a potential source of investigated chemicals.

c. Production method does not contain a control step for investigated chemicals.

d. Potential for contamination between manufacturing and packaging.

e. Potential for contamination during distribution or consumer handling.

f. No method for consumer to detect, remove or destroy hazard if present

The associated risk level (0 to 6; lowest to highest) is then assigned on the basis of the number or types of risk characteristics identified, e.g. Risk Level:

6. Highest category; reserved for any products with 'A' characteristics.

5. All five general characteristics (all five of **B**, **C**, **D**, **E** and **F**).

4. Any four general characteristics (any four of **B**, **C**, **D**, **E** and **F**).

3. Any three general characteristics (any three of **B**, **C**, **D**, **E** and **F**).

2. Any two general characteristics (any two of **B**, **C**, **D**, **E** and **F**).

1. Any one general characteristics (any one of **B**, **C**, **D**, **E** and **F**).

0. No identified hazard characteristics.

Semi-quantitative methods are another option, wherein the hazard analyst assesses the likelihood of hazards occurring. For instance, in a recent HACCP study on packaging materials, **Bovee et al.** (**1997**), outlined a relatively straightforward semi-quantitative approach. In this method, hazard analysts employ their own judgment to assign scores to hazards on a scale of 1 to 4 based on the probability of occurrence (ranging from unlikely to common) and the severity of the hazard (from low to very high). Subsequently, the associated risk can be determined using risk matrices (Table 1).

Tableau 16. Risk ranking scheme based upon severity of risk (S) and probability of hazard (P) as described by **Bovee et al.** (**1997**).

Severity of hazard (S)	**Probability of occurrence (P)**			
	Unlikely (1)	**Occasionally (2)**	**Probable (3)**	**Common (4)**
Very high (4)	2	3	4	4
High (3)	2	3	3	4
Medium (2)	1	2	3	3
Low (1)	1	1	2	2

More quantitative risk analysis approaches involve estimating the likelihood of a hazard occurring by comparing the level at which a contaminant (such as microorganisms, chemicals, or foreign bodies) is present within food products with the concentration at which it poses a health risk. This can be quantified using metrics like the hazard index:

$$HI = \frac{[Food]Contaminant}{\text{Hazard Contaminant}}$$

Where HI is the hazard indices, [Food] Contaminant is the contaminant concentration in the food, and Hazard Contaminant is either the lowest concentration at which the contaminant is believed to be a hazard or the highest concentration at which the contaminant is not believed to be a hazard to human health.

Each approach has advantages and disadvantages. For example, hazard classification and semi-quantitative hazard analysis are readily applicable to many hazards, but they are subjective. More quantitative risk assessment procedures are less subjective, but require more information (e.g., estimated or quantified exposures for ingredients, assessments of exposure pathways, consumption level data, dose-response assessments for individual hazards) that may not be readily available for all hazards considered. Furthermore, a high level of skill and experience is required to employ and interpret quantitative risk analysis data, and this may limit the use of such procedures within HACCP (**Ropkins and Beck, 2000**).

Practically, HACCP is better suited to hazard assessment methods, easy to interpret, and cost-effective. The methods discussed by Lee and Hathaway and Untermann are arguably some of the most practical hazard assessment approaches that could be consistently employed (refer to **Figure 17**).

Once you've determined the hazards that need to be addressed, it's essential to identify the relevant Critical Control Points (CCPs). A CCP is a specific juncture where control is absolutely vital to ensure the safety of the food product. Accurately designating CCPs is crucial for the efficient, effective, and economical implementation of monitoring, control, and corrective procedures. Assigning CCPs is a complex process, and misallocation has been recognized as a significant factor leading to ineffective HACCP systems. The primary criteria typically considered for CCP assignment include:

1. At which point (or points) could the identified hazard either occur or develop to an unacceptable level?
2. Do preventative measures exist for identified hazard and at what point (or points) could these be employed?
3. At what point (or points) could the identified hazard be most effectively controlled?
4. Were any steps specifically designed to eliminate or reduce the identified hazard to an acceptable level?

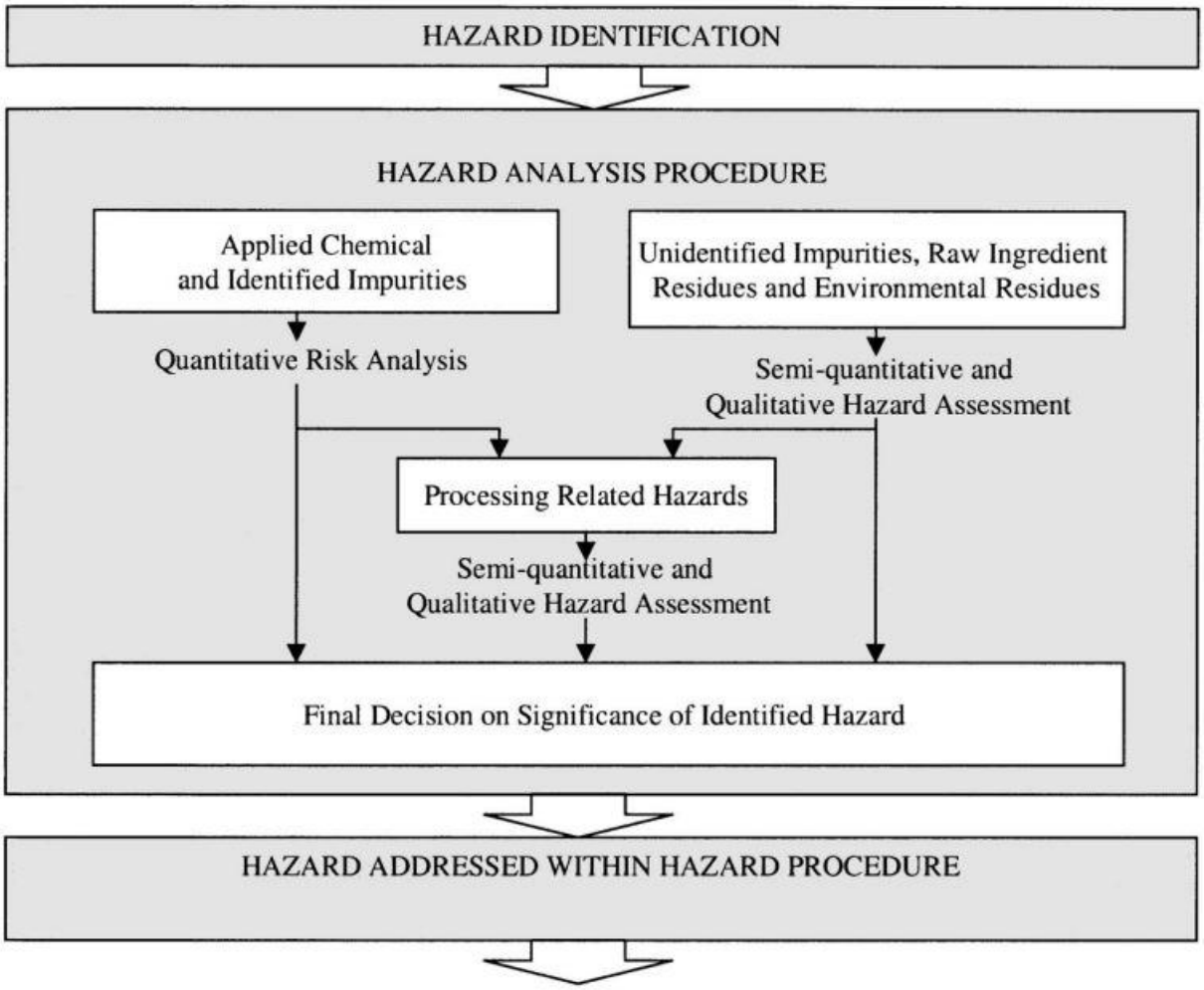

Figure 17. Example of the Combined Use of Quantitative, Semi-Quantitative and Qualitative Approaches with Hazard Analysis (**Ropkins and Beck, 2000**)

Step 7. Identification of Critical Control Points (CCPs).

In HACCP, an activity or operation that affects food safety is defined as a control point (CP) and a control action is any activity or operation that can eliminate or reduce an existing hazard, or prevent subsequent hazard development. A CP that is critical to food safety is a CCP. The accurate assignment of these CCPs is crucial to effective HACCP.

ISO 22000 restructures the traditional concept of distributing control measures into two groups (prerequisites and measures applied to Critical Control Points (CCPs)) in a logical order for the development, implementation, and control of the food safety management system. The control measures are divided into three groups as follows:

- Prerequisite Programs (PRP), which govern basic conditions and activities. PRPs are not selected to control specific identified hazards but to maintain a hygienic environment for production, processing, and/or handling;

- Operational Prerequisite Programs (oPRP), which govern control measures identified by hazard analysis as necessary to control identified hazards at acceptable levels and are not managed by the HACCP plan;
- HACCP Plan, which governs control measures identified by hazard analysis as necessary to control identified hazards at acceptable levels and are applied at Critical Control Points (CCPs).

Subsequently, hazard analysis allows for the identification of relevant hazards to control, the level of control required to ensure food safety, and the corresponding combinations of control measures (PRP and CCP). In some cases, hazard analysis may also lead to a redefinition or requalification of previously established PRPs.

Confusion can arise because, by definition, both PRP and oPRP are considered "prerequisites." Logically, these two means should be regarded as prerequisites for any hazard analysis process. In reality, oPRP align more closely with CCPs and, like them, result from hazard analysis implemented after the implementation of PRP ((**Boutou, 2008**).

The set of control measures consists of PRP, PRPo, and/or the HACCP plan

The fundamental differences between these three concepts are presented below:

PRP: These are the basic conditions and activities applied to infrastructure, personnel, and the work environment necessary to maintain the required hygiene conditions. They represent the general hygiene best practices within a sector of the food chain (cleaning plan, pest control, dress code, etc.). PRPs should be verified.

oPRP: A "specific" PRP identified by hazard analysis as essential for ensuring the safety of food products, requiring validation, monitoring, and verification. A PRPo is a PRP with enhanced control measures due to its critical role in ensuring food safety.

CCP: A "critical" step at which a control measure (identified through hazard analysis) can be applied and monitored in a timely manner, potentially essential for the safety of food products. These critical control measures must be validated, monitored, and verified.

RopkinsThe Table 17 presented here as a summary to highlight the fundamental differences between PRP, PRPo, and control measures at CCPs regarding various concepts. It is extracted from the NF V 01-006: 2008 standard.

Tableau 17. Illustration des différences entre PRP, PRPo et CCP

PRP (BPH)	oPRP	CCP
mandatory prerequisite implementation	Results from the hazard analysis.	
Hygiene control measures.	Measures to be implemented for hazards not controlled by PRPs (Pre-Requisite Programs).	
Non-specific measures.	Measures specific to each hazard or group of hazards	
Measures related to the environment.	Measures related to both the environment and the product	
		Compulsory validation
		Measurable critical limits are associated with each CCP
		Monitoring the implementation of control measures
		Recording of monitoring
		Corrective actions and corrections
Planned verification of implementation	Planned verification of implementation; verification of effectiveness	

Classification of Control Measures: An organization can decide that a maximum number of control measures are managed by oPRPs and only a few by the HACCP plan, or vice versa. It should be noted that in some cases, no CCP may be identified, for example, when monitoring results cannot be provided within an adequate time frame. Since the effects of combining control measures are validated before categorization, food safety is achieved even in cases where all control measures are managed by oPRPs.

The following factors can assist the organization in categorizing control measures:

- ✓ The impact of a control measure on the hazard level or its frequency of occurrence (the greater the impact, the more likely the control measure belongs to the HACCP plan).
- ✓ The severity of a hazard to consumer health that the selected measure must control (the higher the severity, the more likely the measure belongs to the HACCP plan).
- ✓ The need for monitoring (the greater the need, the more likely the measure belongs to the HACCP plan).

To assist the HACCP team in categorizing control measures, ISO/TS 22004 standard provides a decision tree **(Figure 18).**

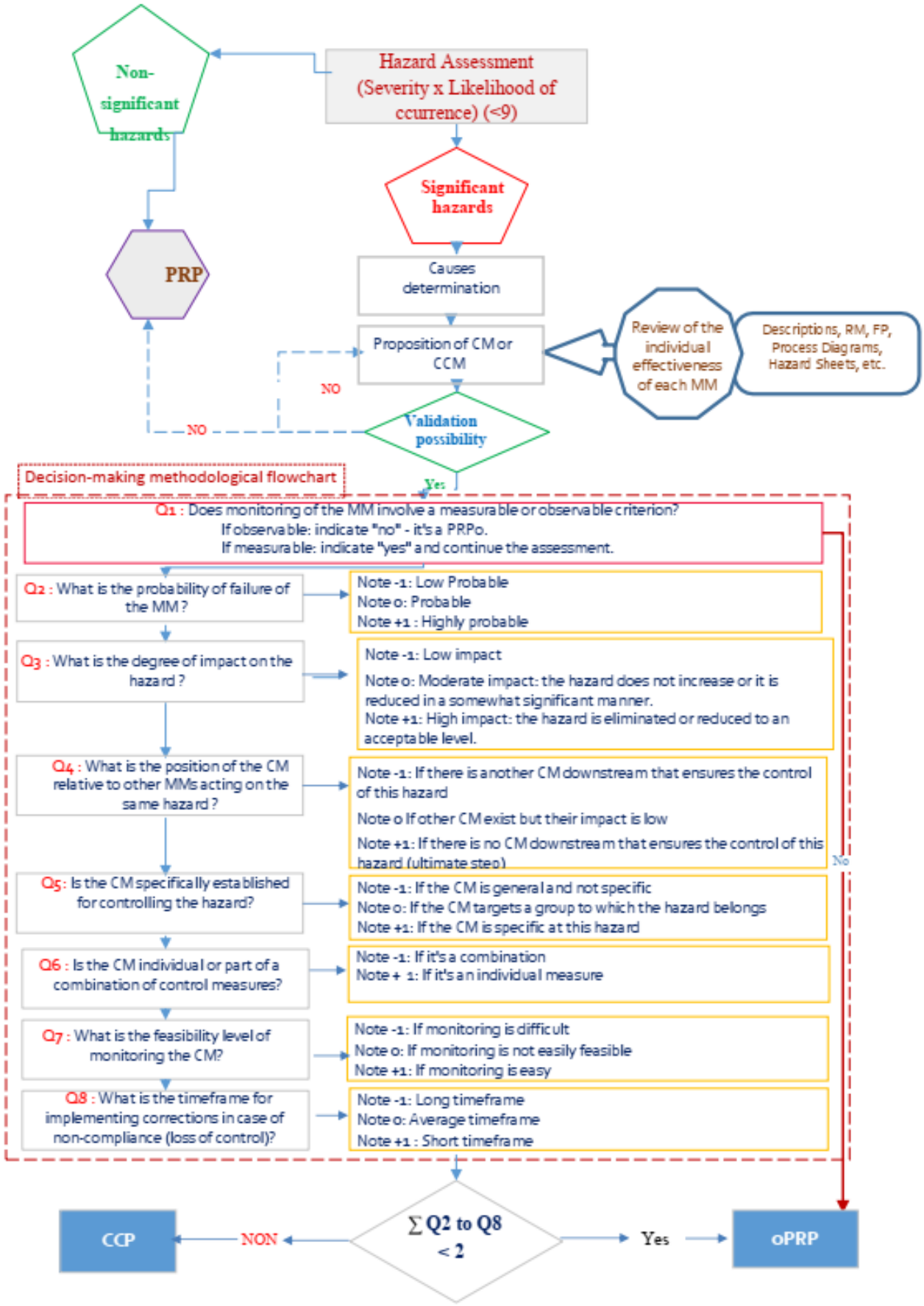

Figure 18. Decision tree (**ISO 22000, 2018**)

Tableau 18. Synthesis of step 7 (Identification of Critical Control Points).

HACCP Phase	Food safety	Resources/Means	Documentary system
Determining Critical Control Points (CCP).	Selected hazards: Biological, Chemical, Physical. (Combination of) control measures essential for a hazard.	Product description. Flowchart and description of process steps. Hazard analysis and control measures. Decision tree(s)/classification of control measures. Monitoring capability of the CCP (measurable criteria). Possible direct actions on the product and the process.	Initialization of the HACCP plan. Initialization of the PRPo management document.

Step 8. Establish critical limits for each CCP.

Critical limits must be established for the monitoring established for each CCP. Critical limits must be set to ensure that the identified acceptable level of food safety-related hazard in the finished product is not exceeded. Critical limits must be measurable.

The reasons for selecting the chosen critical limits must be documented. Critical limits based on subjective data (such as visual control of the product, process, handling, etc.) must be supported by instructions or specifications and/or initial and professional training.

The concept of critical limit is fundamental to the distinction between PRPo and CCP. The difference lies in the fact that for a step considered a Critical Control Point (CCP), it is possible to determine a measurable parameter, and therefore quantifiable, and assign it a value known as the "critical limit."

Critical limit: A criterion that distinguishes acceptability from unacceptability.

Critical limits must also comply with legal requirements, Good Manufacturing Practices (GMP), and/or standards set by the organization, and/or be supported by other scientific data. Maintaining these parameters within the specified range will confirm that the resulting product is safe.

Tableau 19. Establishing critical limits for each Critical Control Point (CCP).

HACCP phase	Food safety	Resources/means	Documentary system
Determining the critical limits for each Critical Control Point (CCP)	Microbiological criteria, maximum limits for residue, maximum limits for physical contaminants. Pasteurization value: Vp, Sterilization value: Vs, Cooking value: Vc.	Critical and operational limits objectively established based on: publications, articles, advice from technical centers or experts, measurements, and tests (e.g., Pasteurization value, Sterilization value, challenge test, analysis of Use-By Date for example), predictive microbiology software, limits within regulatory tolerances where applicable.	CCP monitoring sheet, ad hoc procedures, job sheets, ad hoc operating procedures, control chart, self-monitoring records.

Step 9. Establish a monitoring system for each oPRP and each CCP

The aim is to ensure control of the hazard at each oPRP and each Critical Control Point (CCP).

The criterion 'monitoring' is one of the discriminating factors between oPRP and CCP. In the professional context, two types of monitoring are commonly encountered:

Continuous: Ideal as it allows real-time recording of monitoring and immediate action, especially when triggering corrections and/or corrective actions.

Discontinuous: Requires quickly accessible binary-type responses and a defined frequency.

For discontinuous monitoring, the frequency should be determined based on the product and process history. The following questions can help determine the correct frequency:

- ✓ What is the normal process variation (historical data)?
- ✓ How close is the operational limit to the critical limit?
- ✓ What quantity of product can be 'sacrificed' if there is a deviation from the CCP's critical limit or the PRP's operation?"

The monitoring specifications for each control measure/critical limit must be described and provide information about:

- ✓ Personnel (job position, required skills for measurements and interpretations, versatility);
- ✓ Nature and principle of tests, methods, and techniques used;
- ✓ Location (surface, core of the product, which cooking plate, specific spot on the plate...);
- ✓ Frequency of observations and/or measurements and their locations;

- ✓ Equipment to be used (with what measurement uncertainty), operating procedure, and sampling plan if applicable;
- ✓ Information dissemination.

For each CCP, a monitoring system must be established to demonstrate that the CCP is under control. This system should include all scheduled measurements or observations related to critical limit(s). The monitoring system should consist of procedures, instructions, and relevant records covering the following points:

a. Measurements or observations providing results within an appropriate timeframe;

b. Monitoring devices used;

c. Applicable calibration methods;

d. Monitoring frequency;

e. Responsibilities and authority associated with monitoring and evaluating monitoring results;

f. Recording requirements and methods.

The monitoring methods and frequency should allow for timely determination of exceeding critical limits, enabling the isolation of the product before its use or consumption.

Step 10. Establish corrections and corrective actions

Corrections and corrective actions must be implemented as soon as a critical limit is exceeded and/or when a PRP is no longer under control. Many mistakes have been made in using these terms because the *Codex Alimentarius* combines these two concepts (corrective measures).

In case of exceeding critical limits or loss of control of a PRP, the personnel responsible for monitoring must initiate corrections and corrective actions. Correcting a non-conformity involves an immediate treatment of perceived undesirable effects. The implementation of these actions will be subject to a written procedure.

Step 11. Establish verification procedures

This step is intended to determine if the HACCP system is functioning correctly and, if necessary, identify defects that need to be rectified.

The verification involves four main activities, which are established once the HACCP system is implemented:

- Tests and simulations at CCPs;
- Verification and/or validation of changes made to PRPs or critical limits of CCPs;
- Audits of the HACCP system;
- Checks to ensure that the HACCP system is still appropriate:
  - ❖ Reviews of system documentation;
  - ❖ Targeted sampling and analysis of products;
  - ❖ Calibration and management of measuring equipment;

- ❖ Equipment maintenance and upkeep;
- ❖ Examination of customer complaints.

Step 12. Establish documentation and archiving

The HACCP documentation system plays a crucial role in many aspects:

- It ensures the preservation of organizational knowledge (organizational memory).
- It provides up-to-date documents at the right place and time (working tool).
- It demonstrates the organization's sound structure through formalization of its activities.
- It instills confidence in stakeholders by showing that the organization is well-organized.
- It helps in the integration of new employees (internal initiation and training tool).
- It influences internal behavior, improving consistency and efficiency.
- It, as appropriate, creates, enhances, or restructures hygiene culture.
- It provides the opportunity to review and analyze the relevance and effectiveness of HACCP system actions.
- It guides employees and facilitates their tasks.

The HACCP documentation system primarily involves internal documents (procedures, operating procedures, specifications, etc.) and records.

Tableau 20. Objectives and Purpose of Various HACCP Documents

Objectives	Purpose
HACCP Plan	
Determine the control elements for critical control points (step, hazard, control measure, critical limit, monitoring, corrective action, record).	Ensure effective control of the food safety of products produced by the organization.
HACCP procedures	
Provide information on how to perform various activities (receiving inspection, CCP monitoring, calibration, withdrawals, corrective actions, etc.).	Answer the questions: Who does what? How? Where? When? Define responsibilities and areas of application in case of choices or decisions to be made
HACCP instructions	
Provide information on how to carry out the different stages of the product realization process, procedures, etc.	Answer the questions: Who? and How? which limit the choices. The instruction should be simple and directive
HACCP records	
Demonstrate the execution of an activity, procedure, instruction, or other tasks	Provide irrefutable evidence of the completion of the activity, especially during an audit

8. Successful HACCP implementation

The main constraints for the implementation of food assurance management systems were listed as being time, resources, money, and training in noncommercial food operations (**Riggins and Barrett, 2008**), but these also apply perfectly to commercial food operations.

Similar to any other system, the effectiveness of quality assurance hinges on individuals being informed about the goals, fully persuaded of their significance, engaged in understanding how the system operates, and committed to ensuring its continual, appropriate functioning. It's crucial to understand that no company can successfully implement HACCP (Hazard Analysis and Critical Control Points) without having well-trained members on its HACCP team (**de Oliveira et al., 2016**).

It is necessary to make it clear that both large and small food businesses will face barriers and difficulties in the implementation of food-safety assurance programs; however, as large companies have more resources, technical expertise, and management skills, and small companies have less technical resources, time, people, and financial power.

Mol et al. (2014), analyzing the fish-processing industry, reported the major barrier to HACCP implementation is employee education: as the fishing industry is based upon seasonal employment, it is very difficult to carry out the necessary training and worker development required to implement HACCP systems. **Table 17** below presents the most common reasons for unsuccessful HACCP implementation.

As one of the greatest HACCP requirements is documentation, a record-keeping culture is necessary. It has to be based upon the minimum necessary controls, with the smallest number of CCPs that translate necessary recordkeeping and can be integrated into existing practice (with minimal disruption), if managers believe it makes good business sense. It is also evident that the typical owner-manager has yet to be convinced that HACCP is either effective or practical in the context of their businesses (**de Oliveira et al., 2016**).

Tableau 21. Barriers Listed in the Literature for Successful HACCP Implementation (**reported by de Oliveira et al., 2016**)

Type of company	Barriers listed
Small and medium companies	Insufficient technical resources; concentration of functions; time; financial power
Restaurants	Lack of Resources; lack of corporate policy/standard procedures; lack of knowledge; insufficient financial resources to train personnel; high turnover rates; training efforts are inadequate or not taken seriously; food handling practices cannot be considered CPPs; monitoring practices used (visual and sensory) may be too subjective to be adapted as HACCP monitoring procedures.
Food and catering industry	Management involvement; education and training; availability of resources; and external pressure; barriers before implementation are illusion of control, size of the company, type of product/industry sector, and safety requirements of consumers; barriers during implementation are management, staff, and infrastructure; barriers after implementation are difficulty in validating and in determining the equivalence of HACCP plans.
Small companies	Need for change; need for expertise (in the system and in food safety); time and money; need for documentation; validation of CCPs and verification of the system has to be based on evidence, not on habits and practice; need to find accredited suppliers.
Food processing sector	Weak incentives for voluntary adoption; difficulty and costly to be implemented; no tangible benefits; system is seem as difficult to be adapted to different business sizes and operations;
Food industry	Lack of awareness; no perceived benefits; lack of training; management changes; variability of production lines and products; variability of the consumers' demands; small size of the company; cost of development; application and maintenance of the system; lack of management commitment; lack of personnel training; HACCP legislation alone cannot provide adequate motivation.
Fishing industry	Inadequate and difficult employee education; unpredictability of the availability and prices of raw material; inadequate audit polices; lack of information/ knowledge; excess bureaucracy.

9. HACCP Benefits

The overall benefit is that HACCP is a very effective method of reducing risk of failure and maximizing product safety.

Traditionally many specific benefits are highlighted, including the following:

- ✓ HACCP helps with prioritization in making informed judgments on food safety matters and removes bias, ensuring that the right personnel with the right training and experience are making the decisions.
- ✓ HACCP will also help to demonstrate effective food safety management through documented evidence which can be used in the event of litigation.
- ✓ HACCP can, after the initial setting up of the system, be extremely cost-effective.
- ✓ First, by building the controls into the process, failure can be identified at an early stage and therefore less finished product will be rejected, which means less waste.
- ✓ Second, by identifying the CCPs, the technical resource can be focused on their management.
- ✓ HACCP enables food companies to meet their legal obligations to produce safe, wholesome food.
- ✓ The disciplines of applying HACCP are such that there is almost always going to be an improvement in product quality. This is primarily due to the increased awareness of hazards in general and the participation of people from all areas of the operation.
- ✓ The Global Food Safety Initiative (GFSI) is founded on both the HACCP principles and the support systems needed for a strong food safety program. HACCP is a means to gain certification to schemes which are benchmarked to this global standard.
- ✓ Finally, food safety failure is very costly, not just in the cost to human life. HACCP and food safety systems are a sound business investment. Brand damage and company reputation are hard to put a price on (**Wallace and Mortimore, 2016**)

A control measure is essential if the loss of control at this level means that the product becomes potentially hazardous for the specific batch. This occurs when no subsequent step can eliminate or reduce the hazard to an acceptable level.

10. Traceability in a food supply chain

Traceability is a tool for achieving a number of different objectives and food is a complex product. The definition of food traceability is found different depending on the sector of the food industry **Golan et al. (2004)**. According to the **Wilson and Clarke (1998),** the traceability as the information necessary to describe the production history of a food crop, and any subsequent transformations or processes that the crop might be subject to on its journey from the grower to the consumer's plate. Furthermore, the food traceability is defined as a part of logistics management that capture, store, and transmit adequate information about a food, feed, food-producing animal or substance at all stages in

the food supply chain so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time (**Aung and Chang, 2014**).

10.1. Traceability in the food industry

The important area with regard to traceability is food product recall, a growing concern for food companies. **Kumar and Budin (2006)** presented the prevention and management of product recalls in the processed food industry. Findings from analysis suggested potential reduction of product recalls through recommended preventive measures including the use of the HACCP.

Based on the requirements of traceability in the food chain, a conceptual framework is considered in this paper (Fig. 4). In this framework, all supply chain actors are considered to have internal and external traceability in order to achieve the whole supply chain traceability. The safety and quality regulations enforce all actors to apply safety and quality assurance systems that comply with regulations and tomanage all their operations in an efficient and standard manner. For supply chain operation and performance, enabling technologies can be seen as facilitators which serve as a mediumfor all actors to enable access to food traceability information systems (**Aung and Chang, 2014**).

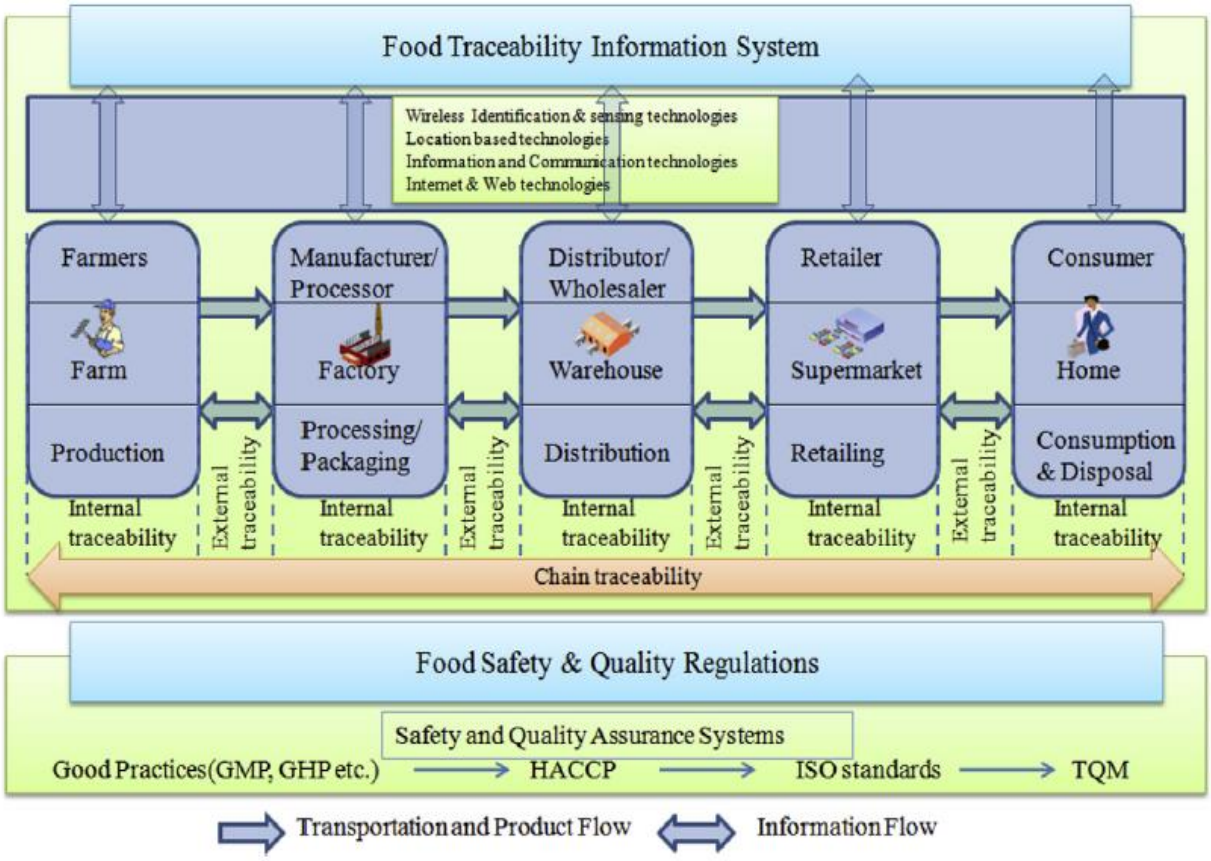

Figure 19. Conceptual framework of food traceability system (**Aung and Chang, 2014**).

10.2. Technologies applied

The technologies applied for the tradability system in food industry include hardware (such as measuring quipment, identification tags and labels) and software (information systems). Advances in information and computer technology for information systems management; scanning and other digital technology for product identification, image capture, storage and display; nondestructive testing and biosensors for quality and safety assessment; and geospatial technologies (Geographic Information System (GIS), Global Positioning System (GPS), Remote Sensing (RS)) for mobile assetstracking and site-specific operations, are technological innovations that can be applied in a traceability system. Basically, a product traceability system requires the identification of all the physical entities (and locations) fromwhich the product originates, that is to say, where it is processed, packaged,andstocked, includingevery agent in the supply chain (**Aung and Chang, 2014**). A summary of the fundamental technical instruments available is shown in Table 19.

Tableau 22. Technical instrument for traceability (**Aung and Chang, 2014**).

Technology	Description	Strengths	Weaknesses
Alphanumeric codes	Label which includes a sequence of numbers and letters of various sizes, Replaced by bar code	Simple to use and economic	Code read/write not automatic Poor performance High data integrity corruption No standards defined Lack of tie between different actors Cannot collect environmental information (no sensing capability)
Bar codes	Optical machine readable representation of data, Encodes alphanumeric characters and consist of vertical bars, spaces, squares and dots	Simple, more economical and exact traceability	Reading need line of sight Unreadable for damaged labels Can read one at a time by scanner Cannot collect environmental information (no sensing capability)
Radio Frequency Identification (RFID)	Detect presence of tagged objects, Identify or track using radio waves	No line of sight in reading, Can read and write tags Higher data rate and larger memory size Reversible tags, Can read many tags simultaneously	Rely on Reader for data collection, A tag cannot initiate communication, No cooperation among the devices, Can read data within one hop Cost still a burden Limited capability for environmental sensing
Wireless Sensor Network (WSN)	Collect sensing data from physical or environmental conditions, Variety of sensors available for sensing and monitoring	Multihop networking, In-network processing, Can deploy different network topologies, Secure communication among nodes, Longer reading ranges Sensor-actuator networking	Not suitable for identification purpose, Need energy saving techniques for continuous sensing

10.3. Problems in food traceability

There are some problems to handle regarding traceability (**Aung and Chang, 2014**). such as:

- ✓ The costs associated with putting traceability systems into place are seen as barriers for supply chain actors especially for small-scale producers from less developed countries;
- ✓ the exchange of information in a standardized format between various links in the chain;
- ✓ Robust mechanisms are needed to facilitate the collection and authentication of any information, to enable it to be updated and shared through the chain;
- ✓ Products such as grain, coffee, olive oil, rice, and milk from multiple farms are combined in silos and storage tanks, making it difficult to trace them back to their sources;
- ✓ biggest challenges of food chain traceability is the extensive use of the manual exchange of information between companies;
- ✓ The adequate knowledge on diverse characteristics of food is important in the food industry. For example, in the fresh produce industry, the development of traceability systems has been greatly influenced by the characteristics of the product;

Chapter VI.

Model for implementation in a food company

Chapter VI. Model for implementation in a food company

The study aims to provide technical information on the development and application of hazard analysis and critical control points (HACCP) in one of the popular cake manufacturing companies in Dhaka, Bangladesh. A generic HACCP plan in accordance with legal requirements was created after a detailed analysis of data collected from the company. Every step of the production process was examined for biological, chemical, and physical hazards. Prerequisite program was designed to address some hazards prior to production, thereby simplifying the HACCP plan. *e critical control points were determined by answering the questions in the decision trees. Finally, the HACCP control chart was created to include critical limits, monitoring, and corrective actions as the components of several HACCP principles. One critical control point (CCP) and two operational prerequisite programs (oPRPs) were identified throughout the manufacturing process. This is the first HACCP study aimed at a cake manufacturing company, and it is expected that it would assist process engineers and quality control specialists in designing and implementing control measures (**Jubayer *et al.*, 2022**).

1. Company Description

This study was conducted in a cake manufacturing company located in the Dhaka division of Bangladesh, which was a joint venture manufacturing company between Denmark and Bangladesh. For this study, we chose a freshly formed company that intends to fully implement food safety regulations. Moreover, it was the first specialized cake manufacturing company in Bangladesh. The research was carried out from January to August of 2019. It was classified as a mediumscale plant, with a monthly production capacity of 500 tons and a workforce of around 200 people during the study period. Muffins, plain cakes, fruit cakes, Swiss rolls, and sponge cakes were among the products produced by the company. In addition to the domestic market, the products had begun to be exported directly to international markets. The restructuring was intended to expand the company's market. As a result, the company planned to implement an effective FSMS to ensure consumer food safety and high quality products. This study explains the PRPs, OPRPs, and HACCP principles in accordance with the standard requirements for the cake manufacturing line. The company layout (**Figure 23**) shown below is adopted from the study of **Jubayer et al.** (**2022**).

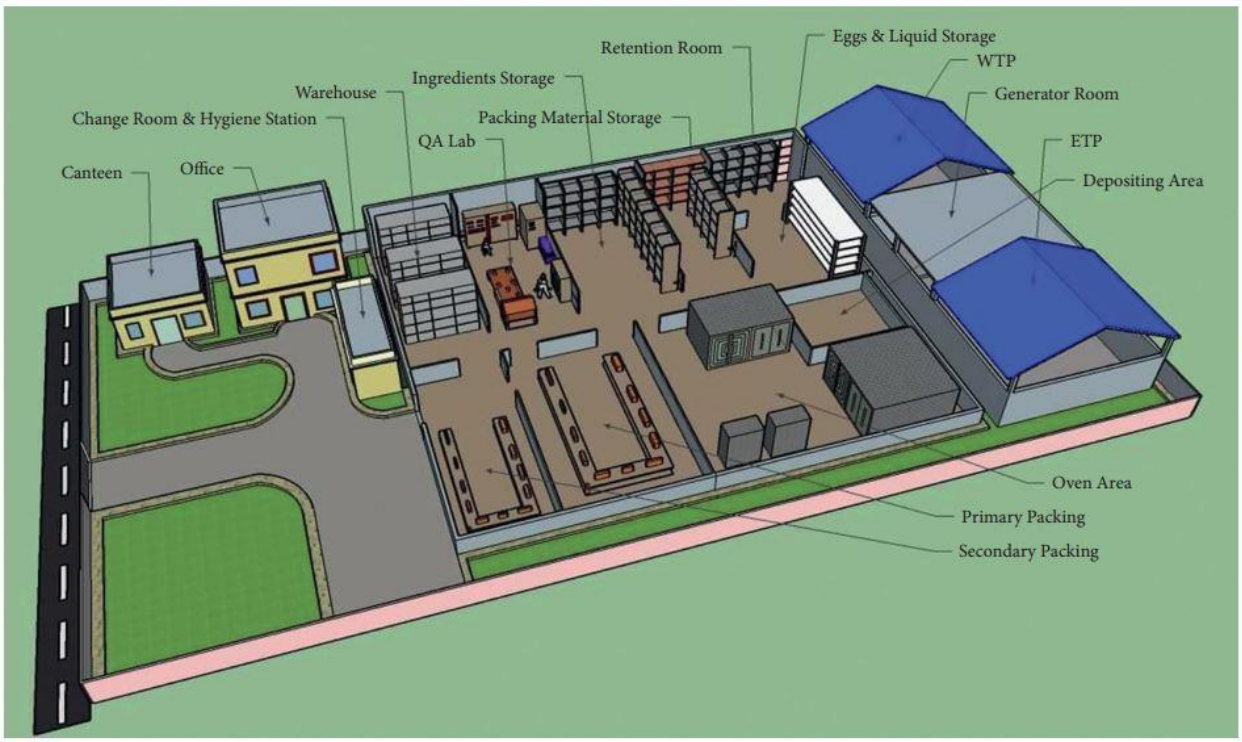

Figure 20. Layout of the plant (**Jubayer et al., 2022**).

2. HACCP Implementation Steps

The tasks outlined in section 7 of ISO 22000: 2005 were followed to develop a HACCP plan that includes the following seven principles:

1. Conduct hazard analysis (HA)
2. Identify critical control points (CCP)
3. Establish critical limits (CL)
4. Monitor each CCP
5. Establish corrective action
6. Establish verification procedures
7. Establish record keeping

In this study, prerequisites programs (PRPs) are included in the HACCP study. Therefore, procedures related to the prerequisite programs are firstly presented (**Wang et al., 2010**).

3. Listing the prerequisite programs (PRPs)

PRPs are formally called support programs that provide foundations for HACCP in overall food safety management program (**da Cruz et al., 2006**). They represent the conditions and the necessary basic activities to maintain a hygienic environment for the production, handling and provision of safe finished products all along the food product process (**Gaaloul et al., 2011; ISO 22000, 2005**). The prerequisite programs in the company are: PRP personnel hygiene, PRP hygiene of buildings and premises, PRP cross contamination, PRP disposal of wastes and used water, PRP water supply, PRP transport and storage, PRP supply management and products handling, PRP maintenance of

equipment, PRP cleaning and disinfection, PRP pest control. These programs are verified according to well-defined frequencies.

Operational Prerequisite Program(s) (oPRP): These are Prerequisite Programs (PRP) that have been identified through hazard analysis as crucial for controlling the likelihood of introducing food safety hazards and/or preventing the contamination or proliferation of food safety hazards in the product(s) or within the processing environment. The components of an oPRP are akin to those of a Critical Control Point (CCP) except that no critical limit is necessary for the control measure(s) (**Cerf & Donnat, 2011**). It is acceptable to have intermittent monitoring, and in case of non-compliance with action limits or action criteria, corrective actions, and, if applicable, corrections should be planned and implemented (ISO/FDIS 22004:2014).

4. Hazard analysis

Identification and assessment of hazards is a key principle for all HACCP systems (**Mortimore, 2001**), and a prerequisite to the protection of public health. To achieve this step, the food safety team established a procedure specifying the methodology for hazard analysis.

This procedure specifies the elements of hazard assessment and identification of CCP and oPRP that apply to the company's various stages of food production (from the receipt of raw materials to the distribution of finished products). It concerns all hazards having a direct or indirect impact on the product.

4.2. Hazard assessment

The food safety team assessed the identified hazards during the scheduled meetings. Hazard analysis was conducted at every phase of ice cream production, with hazards being classified into four main categories: biological (pathogens), chemical (toxic substances), physical (foreign particles), and allergen-related risks. These hazards were primarily associated with contamination, proliferation, and persistence (**Allata et al., 2017**).

The assessment criteria for each hazard involve evaluating two key factors: the severity of known or potential adverse health effects and the likelihood of occurrence. To establish these criteria, information drawn from the company's historical data, customer and consumer complaints, as well as instances of nonconformities, is used to establish different levels of severity and likelihood, each assigned a corresponding score. Likelihood and severity are assessed in accordance with the criteria and scores outlined in **Table 24**. A hazard is deemed significant if the result of multiplying the probability (P) by the severity (S) values (P x S) exceeds 4 (**Fernandez-Segovia et al., 2014**). A significant hazard is one that requires elimination or reduction to an acceptable level in order to ensure the production of safe food.

5. Preliminary Steps to Enable Hazard Analysis

The implementation of a food safety system (HACCP) is an ongoing procedure rooted in the managerial principles of an iterative four-step management approach referred to as the PDCA cycle (which stands for plan, execute, verify, and refine).

The HACCP team. A team was formed to implement an efficient HACCP system. While assembling the HACCP team for the company, the following factors were taken into account. *e team was supposed to have six members.

1. The members of the team should possess expertise and competence in their specific fields of activity.
2. Members should demonstrate expertise and proficiency in their respective areas of specialization.
3. The team coordinator will have the responsibility of creating, executing, and maintaining the HACCP system.
4. All team members are expected to receive proper training;
5. The team is required to create and keep all documents in alignment with the HACCP system.
6. Moreover, in the event of any process change or modification, the team must annually assess the effectiveness of the HACCP system.

The team leader, as the highest authority, is responsible for ensuring the company's smooth operation and compliance with all legal requirements. It is also their duty to oversee all aspects of the plan, as well as the roles and coordination of both internal and external corporate activities (**Marques et al., 2012**).

Product characteristics and intended use: The HACCP team needs to start with a thorough description of the produces, defining their composition and chemical, biological, and physical properties. **Table 23** shows the generic framework for the description of cake.

Construction of flow diagram: A flowchart depicting the entire cake manufacturing process was created **(Figure 21).** The HACCP team conducted an on-site examination of the flow diagrams. It is of utmost importance that the flowchart is meticulously prepared and comprehensively analyzed in the actual production environment, including as much relevant information as possible. Only a well-structured, informative, and carefully scrutinized flowchart can effectively streamline the overall production process, thereby simplifying the detection of potential deviations (**Marques et al., 2012**).

Hazard Analysis and Identification of CCPs and oPRPs: The hazard analysis plays a crucial role in identifying potential risks associated with the entire process, spanning from the receipt of raw materials to the delivery of products to consumers. During the hazard analysis, these risks were further categorized into three main categories: (a) biological, (b) physical, and (c) chemical (**Fernandez-Segovia et al., 2014**).

The primary goal of hazard analysis or identification is to pinpoint potential threats to human health that could be introduced into baked goods during the manufacturing process. Based on this

hazard analysis, subsequent risk assessments were conducted. These risk assessments typically took into consideration factors such as customer complaints, product returns, and laboratory test results. Hazards identified at each step of the process flow diagram were documented in a standardized format. After completing the subsequent process steps, values representing the likelihood of the hazard's presence and the consequences of those hazards were entered into the assessment column. These values were determined as detailed in **Table 24 and Table 25.**

Tableau 23. Product description and intended use (**Jubayer et al., 2022**).

Product	Cake is a bakery product	
Product composition	Wheat flour, sugar, eggs, salt, vegetable fat, glycerol, starch, wheat starch, skim milk powder, raising agents (E 500), preservative (E 202), and flavor	
Product characteristics	Physicochemical characteristics:	
	Moisture	18–22% $_{w}$b
	Water activity (aw)	0.76–0.81
	Acid value of extracted fat, (as oleic acid), percent by mass, max.	1.0
	Protein	5–7 g/100g
	Microbiological characteristics:	
	Total viable count, cfu/g	max. 20000
	Enterobacteriaceae spp.	≤ 102 UFC/g
	Staphylococcus aureus	≤ 102 UFC/g
	Salmonella spp.	Absent
	Listeria monocytogenes	Absent
	Coliform Absent	
	Mold, maximum	50 CFU/g
	Sensory characteristics:	
	Physical condition	Solid
	Color	Characteristics
	Flavor	Typical
	Texture	Typical
Labeling requirements	Product's name, composition, allergen information, origin, manufactures date, expiry date, destination, net weight, storage temperature, and destination	
Storage and transport conditions	Primary packages should be packaged further in a secondary packing procedure (gift boxes). Secondary boxed must packed in tertiary packaging (cartons). Final storage and transportation should make at ambient temperature	
Shelf life	4 months	
Intended use	Direct consumption. the product mentioned is for the general population, except for gluten sensitive groups	
Applicable laws	BDS 1574, specifications for cakes; BDS 1240, specifications for drinking water; BDS 381, specifications for maida; BDS 1567, specifications for refined oil; BDS 79, specifications for jams and jellies; BDS 1615, specifications for cocoa powder; BDS 138, specifications for refined sugar; BDS 207, specifications for milk powder and cream powder; BDS 822, code of hygienic conditions for food processing units, etc.	

6. Flow diagrams

The flow diagram consists in a detailed list of all the stages needed to prepare ice cream. The flow diagram should also include the stages after the product is obtained until it reaches the consumer, in order to establish circumstances that might potentially affect product safety and which should be taken into account (**Martínez-Rodríguez & Carrascosa, 2009**).

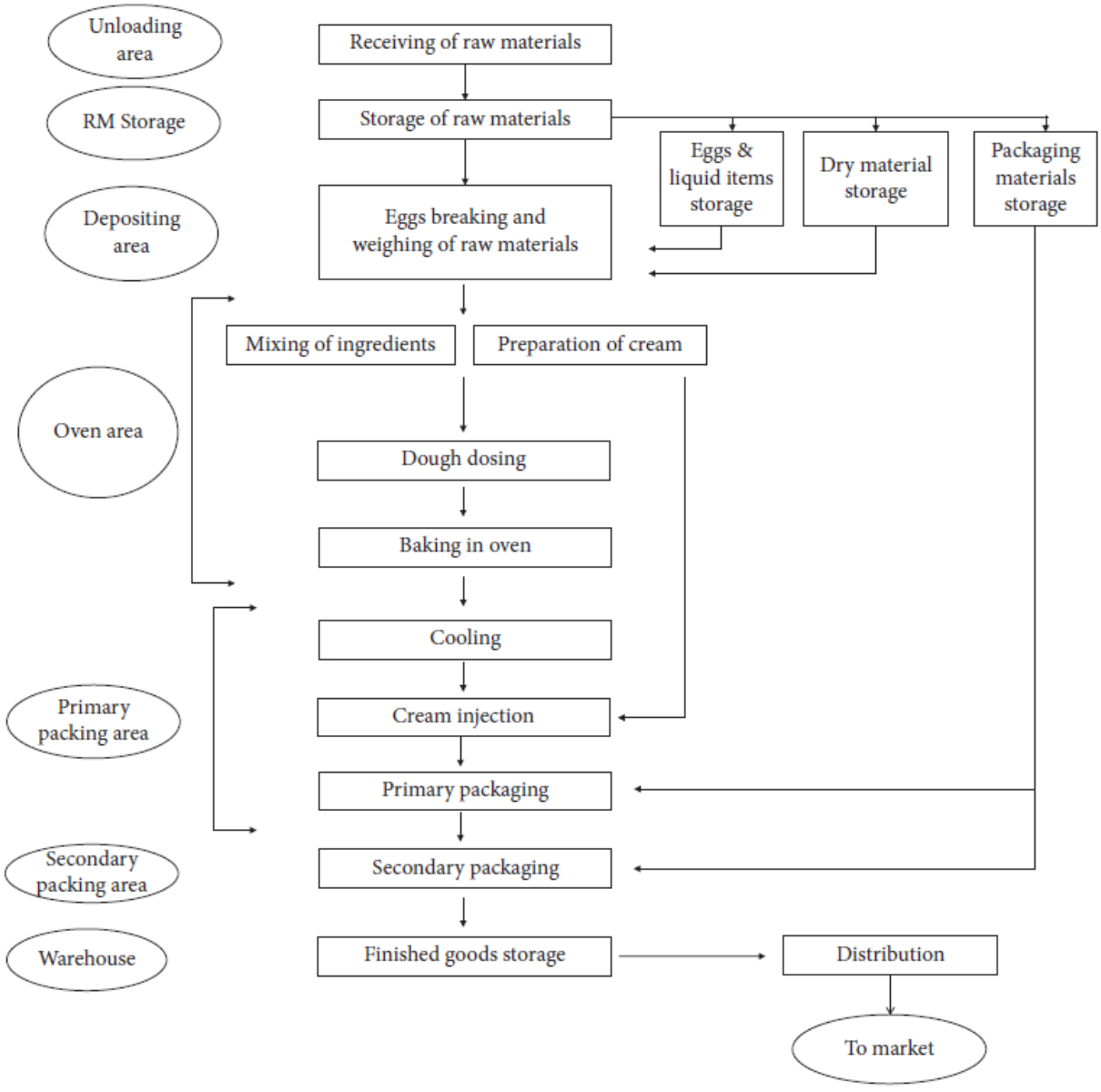

Figure 21. Complete flowchart of the cake manufacturing process (**Jubayer et al., 2022**).

The likelihood, i.e., probability, and consequences of a specified hazardous event occurring are combined to form risk. *us, it can be defined as follows: risk index (RI) = likelihood × consequences.

Tableau 24. Likelihood and consequence criteria to specify potential hazard in cake manufacturing process

Likelihood (probability)	Consequences (severity)
4. Frequent, e.g., daily	4. Very high (catastrophe), e.g., death
3. Likely, e.g., weekly	3. High (critical), e.g., illness
2. Occasional, e.g., monthly	2. Medium, e.g., injury
1. Unlikely, e.g., yearly	1. Minor, e.g., no injuries

Significant hazards were identified using a numerical scale of one (1) to four (4) of likelihood and consequence. When rating likelihood and consequences, previous experiences, records, and data were considered (**Table 21**).

Tableau 25. Analysis of likelihood vs. consequences.

Hazard types	Likelihood (probability)	Consequences (severity)	RI
Physical (stones, sand, husks, and plastic)	X	y	Xy
Physical (stones, sand, husks, and plastic)	X	y	Xy
Biological: total plate count (TPC), coli form, molds, and pests	X	y	Xy

According to Table 3, the index risk (IR) for this current study ranges from 1 to 12. The calculated Risk Index (RI) indicates that if the RI exceeds 8, it should be managed through the implementation of an HACCP plan. An HACCP plan is a documented strategy prepared in accordance with the seven principles of HACCP. Conversely, when the IR is below 4, the results should be maintained by the Operational Prerequisite Programs (oPRPs) (**Wallace and Williams, 2001**). The Risk Index (RI) for the cake production process is detailed in **Table 25.**

Tableau 26. Risk index and its management (**Wallace and Williams, 2001**).

Risk Index	Risk type	Management of risk
RI ≤ 4	Satisfactory risk	Should be managed by oPRPs
4≥ RI≤ 8	Lower risk	
8≥ RI≤ 12	Lower risk	
12≥ RI≤ 16	Critical risk	Should be managed by the HACCP plan

After completing the hazard assessment, appropriate control measures are chosen using the CCP decision tree, as depicted in **Figure 22.** A Critical Control Point (CCP) is a specific step in which a particular control measure must be implemented to prevent or eliminate a food safety hazard or reduce the risk to an acceptable level.

The components of an Operational Prerequisite Program (oPRP) are the same as those of a CCP, with the exception that no critical limit is required for the control measure(s), and failures in the manufacturing process do not have a direct impact on the process. The hazard analysis for the cake manufacturing process is presented in **Table 27.**

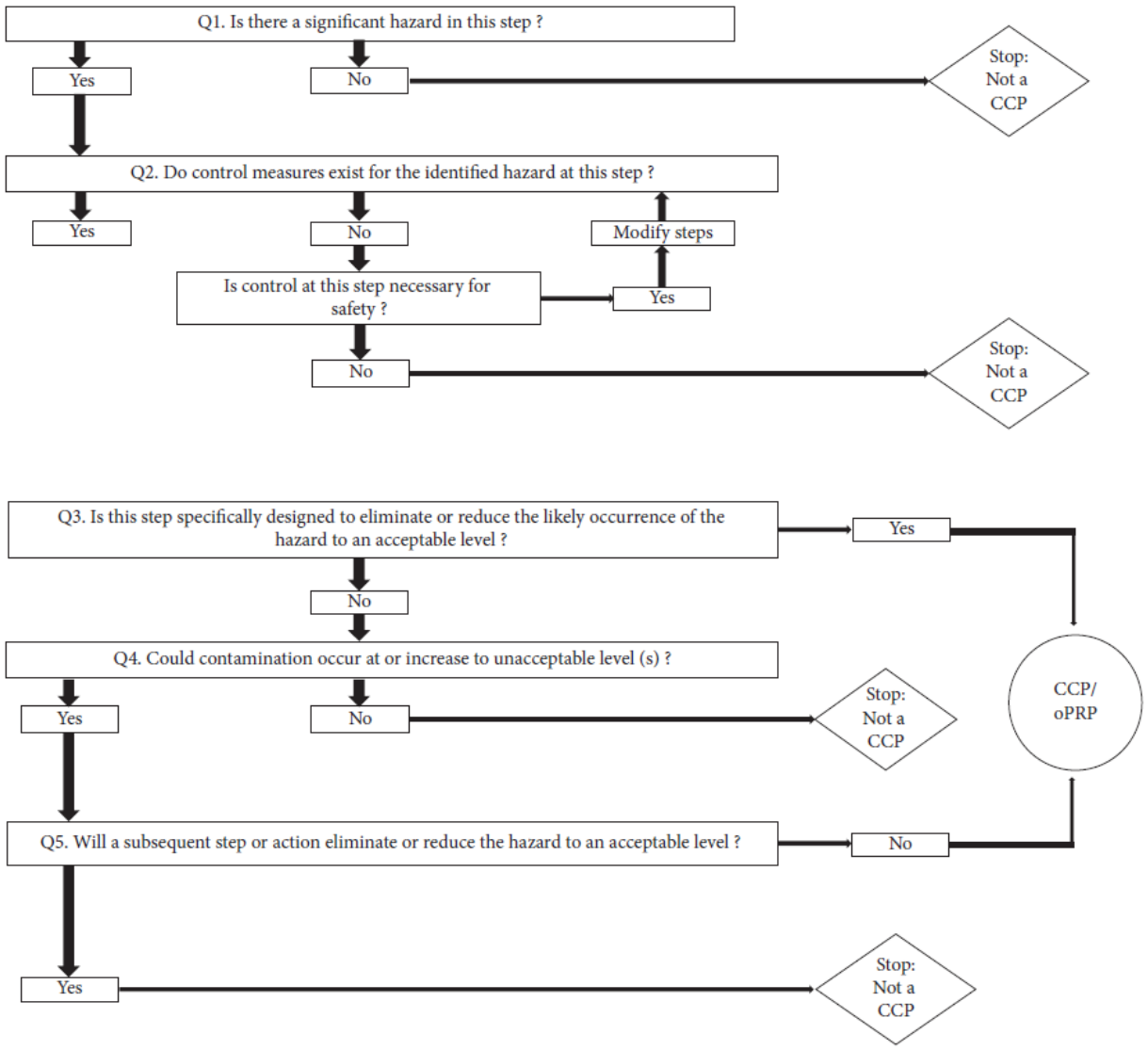

Figure 22. CCP decision tree for HACCP implementation (**reported by Allata et al., 2017**).

7. Establishing the oPRP and HACCP Plan

The HACCP plan was created for each Operational Prerequisite Program (oPRP) and Critical Control Point (CCP), detailing the hazards, control measures, Critical Limits (CL), corrective actions, verification procedures, and record-keeping protocols. Potential control points for hazards were identified in both the raw material and the manufacturing process. Tables 6 and 7 provide information on the oPRP and HACCP plan for the cake manufacturing process.

The HACCP control chart, presented in **Table 27,** illustrates all potential critical hazards that could arise during the various processing steps.

In the cake manufacturing process, one Critical Control Point (CCP) - metal detection, and two Operational Prerequisite Programs (oPRPs) - baking and packaging, were identified. For the baking stage to effectively eliminate vegetative pathogenic bacteria, the center temperature of the bakery product crumb must reach and maintain a temperature above 100°C for a few minutes.

The primary ingredients in cake dough include fats and oils, eggs, flour, and sugar. Among these, sugar is relatively safe in terms of foodborne illness. Fats and oils, however, can potentially be a source of *Listeria* contamination. Flour, on the other hand, carries both chemical and microbial risks, with the most significant concern being mycotoxins, such as aflatoxin.

Even though the physicochemical properties of flour (i.e., low water activity) do not support bacterial growth, microorganisms can survive for extended periods during storage. Eggshells are considered a major source of *Salmonella enteritidis*. However, cake dough is not considered a high-risk food because it has a low water activity and requires baking before packaging and consumption, which effectively eliminates microbial risks.

To ensure the effectiveness of the HACCP plan, the food safety team developed a verification strategy that outlines the objectives, methods, frequency, and responsibilities for conducting verification activities. Records and documentation are created to provide evidence of the system's successful implementation. Various documentation formats were also utilized in our research to oversee specific control measures and ensure appropriate corrective actions. This documentation typically included instances of deviations, the corresponding corrective measures taken, and verification steps. The aspects covered in the monitoring procedure for HACCP included the following: the specific parameter being monitored (object), the method used for monitoring (such as requiring inspection reports), the frequency of monitoring (e.g., for every batch), and the individuals responsible for conducting the monitoring (such as operators) (**Jubayer et al., 2022**).

The current study has identified a noteworthy risk with the potential to affect public health significantly. However, the entire process underwent rigorous systematic monitoring, from the initial stages to the final production, which was of paramount importance for ensuring food safety.

This system is consistently subject to regular systematic monitoring, with Critical Control Points (CCPs) being just one aspect of it. The documentation and data provided by the HACCP system can be instrumental in promptly tracing any contamination. Moreover, this approach has also been effective in preventing cross-contamination. In conclusion, it can be asserted that this approach not only upholds higher quality and hygiene standards but also ensures the superior quality of the cakes produced.

Tableau 27. Hazard analysis for the production process of cake.

Process steps	Hazards	Risk effects	Probable causes	P	S	RI	Control measures (SOP or work instructions)	Decision tree Q_1	Q_2	Q_3	Q_4	Q_5	Record
Receiving of raw and packaging materials	Physical: foreign objects, such as hair, insects, broken plastics.	Without consequences	Packaging, hygiene, pest control	3	1	3	Visual inspection	Yes	Yes	No	Yes	Yes	PRP
	Chemical: acidity, melamine, heavy metals, residual chemical, etc.	Without consequences	CoA, packaging	1	3	3	Supplier evaluation, CoA, HACCP certificate, personal and transport hygiene status, lab test (QA)	Yes	Yes	No	Yes	Yes	PRP
	Biological: microbial contamination (pathogenic)	With consequences	CoA, hygiene	1	4	4	Supplier evaluation, CoA, HACCP certificate, personal and transport hygiene status, lab test (QA)	Yes	Yes	No	Yes	Yes	PRP
Storage of raw and packaging materials	Physical: foreign objects, insects	Without consequences	Irregular inspection and improper hygiene	3	1	3	Keep storage environment safe, keep containers closed. Separate areas for raw and packaging materials	Yes	Yes	No	No	/	PRP
	Chemical: production of H2S (eggs)	Without consequences	Storage temperature	2	1	2	Maintaining suitable storage condition, FIFO	No					PRP
	Biological: microbial, pests and insects	With consequences	Transport and storage temperature, pest control, hygiene	1	4	4	FIFO, maintaining suitable storage and transport temperature, pest controlling plan, maintain personal and environmental hygiene during storage and transport	Yes	Yes	No	Yes	Yes	PRP
Taking RM and PM from storage to production	Physical: foreign objects Chemical: unidentified Biological: unidentified	Without consequences	Improper handling and personal hygiene	3	1	3	Maintain personal hygiene, wear mask, apron, gloves, head cover and beard cover, maintain SOP, GHP	Yes	Yes	No	Yes	Yes	PRP
Batch preparation (weighing and mixing)	Physical: foreign objects, broken egg shells	Without consequences	Improper handling and personal hygiene	3	1	3	Provision of filter in egg broker machine, visual inspection, maintaining personal hygiene, wear mask, apron, gloves, head cover, and beard cover	Yes	Yes	No	Yes	Yes	PRP
	Chemical: excess additives, detergents, etc.	Without consequences	Incorrect hygiene and cleaning, faulty recipe	1	1	1	Follow the recipe and recheck, timely calibration of measuring instruments	No					PRP
	Biological: Pathogenic microorganism	With consequences	Improper personal hygiene	1	4	4	Strict personal hygiene, regular hand swab tests by the QA, proper hygiene, food safety, and behavioral training	Yes	Yes	No	Yes	Yes	PRP
Mixing	Physical: broken piece of mixing machine, foreign objects	With consequences, without consequences	Maintenance of mixing machine, improper personal hygiene	1	5	5	Checking the status of mixing machine, maintain personal hygiene, wear mask, apron, gloves, head cover, and beard cover	Yes	Yes	No	Yes	Yes	PRP
	Chemical: detergents residue	without consequences	Improper hygiene and cleaning practice				Maintain proper hygiene and cleaning practice	Yes	Yes	No	Yes	Yes	PRP
	Biological: pathogenic microorganism	with consequences	Improper personal hygiene				Maintain strict personal hygiene, wear mask, apron, gloves, head cover and beard cover, keep the equipment properly sanitized	Yes	Yes	No	Yes	Yes	PRP
Dosing	Physical: broken piece of dosing nozzle Chemical: unidentified Biological: unidentified	With consequences	Maintenance of dosing machine	1	1	1	Checking the status of dosing machine	Yes	Yes	No	Yes	Yes	PRP
Baking	Physical: unidentified	Without consequences											
	Chemical: moisture content and water activity	Without consequences	Improper baking time and temperature	3	1	3	Frequent lab test for MC and aw from each batch, maintenance of baking temperature and time as per SOP	No					PRP
	Biological: microbial contamination	With consequences	Improper baking time and temperature	1	4	4	Maintenance of baking temperature and time as per SOP	Yes	Yes	No	Yes	Yes	oPRP
Cooling	Physical: unidentified Chemical: moisture content and water activity Biological: unidentified	Without consequence	Improper cooling time and temperature	2	1	2	Check for cooling conveyor speed and cooling temperature	No					PRP
Cream filling	Physical: broken part of cream dosing nozzle Chemical: unidentified Biological: unidentified	With consequences	Maintenance of cream filling machine	1	2	2	Checking the status of cream filling machine	Yes	Yes	No	Yes	Yes	PRP
Metal detection	Physical: metal parts Chemical: unidentified Biological: unidentified	With consequences	Inactive sensor of the metal detection machine, machine broken	3	4	12	Frequent checking of the machine status	Yes	Yes	Yes	No	No	CCP
Packaging	Physical: foreign parts from packaging machine surface, damaged pack, leakage in packing	With consequences	Improper cleaning, shortage of nitrogen gas, PLC fault	3	1	3	Proper cleaning of packaging machine, check for nitrogen gas level, regular checking of the PLC system	Yes	Yes	No	Yes	Yes	PRP
	Chemical: detergents residue	Without consequences	Improper hygiene and cleaning practice	1	1	1	Maintain proper hygiene and cleaning practice	Yes	Yes	No	Yes	Yes	PRP
	Biological: microorganisms	With consequences	Improper personal hygiene, contamination in packing materials	2	4	8	Regular hand and surface swab test, ATP check before packing, strict maintaining of personal hygiene, QA online check for	Yes	Yes	No	Yes	No	oPRP
Filling in box and date coding	No hazard	M	Method (process)	1		5							
Finished goods store	Physical: tertiary package damage by rodents	Without consequences						Yes	Yes	No	Yes	Yes	PRP
	Chemical: unidentified Biological: unidentified	Without consequences	No pest traps and pest contro	2	1	2	Put glue trap in proper places, conduct timely pest control action						

Tableau 28. oPRPs in the cake manufacturing process

				Monitoring procedures						
Processing step	Hazard	Control measure(s)	Critical limit	What?	How?	Who?	Frequency (when?)	Records	Corrective action	Verification
Baking	Biological: microbial contamination	Maintenance of baking temperature and time as per SOP	Baking temperature between 150 and 250 °C for 5–50 minute	Oven temperature	Physical inspection	QA officer, production officer	Every one hour interval	QA and production (plan oPRP	Reset the temperature and time, reject or reuse the product	Physical observation, calibration
Packaging	Biological: microbial contamination	Regular hand and surface swab test, ATP check before packing, strict maintaining of personal hygiene, QA online check for leak package	Surface ATP = <50 RLU; Hand swab for coliform = nil; Hand swab for =mold <50 cfu/ml	Machine surface, Workers hands	Swab test, microbiological test in the QA lab	QA executive	ATP test every day, hand swab test twice in a week	QA and production (plan oPRP)	Reclean the surface, observation (hygiene status) of infected hands (person) for a month, reject the leak pack and products	Recheck

Tableau 29. HACCP control chart

				Monitoring procedures						
Processing step	Hazard	Control measure(s)	Critical limit	What?	How?	Who?	Frequency (when?)	Records	Corrective action	Verification
Metal detection	Physical: metallic component	Physical: metallic component	Absence of metallic component	Sensor of the metal detector, PLC, alarm	Physical inspection and check for alarm (by passing a metal under the metal detector)	Maintenance dept., QA and production dept.	Every 1 hr interval during the production time	QA, production, And maintenance register (plan CCP)	Rejection of the whole lot of nonconformed products	In-house checking by metal pieces, maintenance records, calibration of metal detector, and auditing

8. Establishing the documentation and record keeping

Documentation and records are established to provide evidence of effective implementation of the system (**Mortimore, 2001**). The operational documents are divided into two groups: general procedures and detailed instructions (**Dzwolak & Zuraw, 2003**). The procedure model used in this ice cream company is based on the structure and format based on ISO/TR 10013 (ISO, 2001). Their structural elements are title, purpose, scope/application, definitions & abbreviations, authorities & responsibilities, description of activities, records, related documents, references and attachments.

9. Traceability system and information flow

Prior to its certification (with ISO 22000:2005), MAZAFROID factory adopted an ice cream traceability system while being fully conscious at the outset of the added advantages in achieving traceability and its compatibility with Hazard Analysis Critical Control Point (HACCP). A very simple traceability system was put in place following an effective definition and application of traceability pillars (**Regattieri *et al.*, 2007**).

The first step is the identification of characteristics of product (Steps 2 of HACCP) (**Regattieri et al., 2007**). A raw material sheet is established to document import information regarding raw materials (received), including: the supplier's name, raw material denomination, weight, lot number assigned by the supplier, arrival date. The supplier through a delivered note and a conformity certificate provides this information.

The product routing and the determination of data to trace and traceability's tools to use are the other fundamental steps taken into account in designing this traceability system (**Regattieri et al., 2007**). The product life is recorded along the chain through both production and storage activities. Fig. 1, in the right column, shows the flow chart of the ice cream production process while, in the left column related information flow of the traceability system is described (Steps 5 of HACCP).

Traceability for each lot is ensured thanks to the acquisition of various data during its lifecycle. In storage phase, the raw materials do not require to record that information, since they can be identified by product labels (**Lavelli, 2013**). These materials are then weighed and mixed in blenders. Mixing phase is an information capture point, processing step in which recording information is essential to maintain identification of products (**Peri *et al.*, 2004; Thakur & Donnelly, 2010**). Here, the traceability system establishes a link between the raw materials lot and the lot of ice cream obtained; thus, the product information about the raw materials is related to the final product. Traceability information is manually noted on a production process sheet. This latter document is prepared to record at each production: the name of the final product to be obtained, its lot number, the date of the beginning of the production process, the production date, the raw materials lot, blender code, tank code and the process parameters, the pasteurization and aging temperatures and the pH level. The production process sheet follows the

ice cream lot through all production stages, so that a simple reading of this document provides the complete history of product.

At the end of the freezing phase, the ice cream is put in the packaging, which is marked with the GTIN (Global Trade Item Number) barcode and lot number. This lot number would allow the product to be traced back through company. It is defined by: - Trade item code: Company encoded its products and this encoding is made up of letters and Arabic numbers (**Hu *et al.*, 2013**);

- Blender code: the blenders where the mix is mixed;
- Tank code: the tank where the mix is aged;
- Processing date: represent the date of the beginning of the process.

Structure of ice cream lot number coding is shown in Fig. 5.

The last step of production process is product delivery to the customers. At this step it is mandatory to link the lot number and amount of the product obtained to the customers' names (**Lavelli, 2013**). A delivery note detailing the name and lot number of the final product, customer's name, and date of shipping must be filled. GPS antennas ensure traceability in the distribution chain. Such system would make it possible to track the product even when the process works irregularly such as delays caused by weather conditions.

The management of the information included in the several information capture point defined along the ice cream production process related on: the correct identification of information content, location and retrieval (**Bertolini *et al.*, 2006**). **Table 26** presents the information to be captured and methods used to record it in MAZAFROID.

Conclusion

The HACCP system provides food manufacturers with effective preventive methods for ensuring food safety and improving the quality. Furthermore, the documentation and records generated by the HACCP system can easily assist in tracing the source of contamination, preventing further production of substandard products and reducing the consumption of manpower, material, and financial resources.

The current study developed a HACCP plan for a cake manufacturing plant in Bangladesh in order to improve product safety and quality. *e hazards in cake manufacturing are primarily due to the use of improper processing conditions, an unsanitary manufacturing environment, and a lack of legislative implementation. We found a CCP and two oPRPs in the entire cake manufacturing process. Further linking of the HACCP system introduced in the factory for quality management systems, such as International Organization for Standardization regulation, can potentially provide higher quality/hygiene standards, as well as increasing customer awareness. However, rather than establishing the HACCP system, management teams of food corporations should ensure the application of the HACCP system in their entire production system (**Jubayer et al., 2022**)

Conclusion

Conclusion

The exploration of food safety and quality is a multifaceted journey that necessitates a comprehensive understanding of various aspects, ranging from standardized analytical techniques to effective implementation models in food companies. This series of chapters delves into crucial components that collectively contribute to the assurance of safe and high-quality food products. Through the lens of standardized analysis, sampling techniques, labeling standards, the HACCP system, and practical implementation models, this exploration aims to illuminate the intricate web of considerations involved in safeguarding the integrity of the global food supply chain.

Standardization in food analysis techniques is not merely a technical necessity; it is the bedrock of credibility and trust in the food industry. This chapter underscores the significance of consistent methodologies for evaluating the composition and safety of food products. By establishing a common ground through standardized techniques, stakeholders across the food supply chain can communicate transparently, fostering a culture of reliability and adherence to regulatory standards.

Effective sampling techniques form the cornerstone of accurate food analysis. This chapter delves into the methodologies that ensure the representativity and reliability of sampled materials. Emphasizing the importance of meticulous sampling processes, it seeks to equip professionals with the knowledge and skills needed to obtain meaningful samples for precise analysis, ultimately contributing to the robustness of food quality and safety assessments.

Food safety is not a luxury but a fundamental right for consumers worldwide. This chapter navigates the landscape of food safety, addressing critical considerations such as hygiene practices, microbial control, and contamination prevention. A proactive approach to food safety is explored, aiming to empower individuals and organizations to uphold the highest standards in food production, thereby safeguarding public health and trust.

Transparent and informative food labeling is a cornerstone of consumer empowerment. This chapter explores the Codex General Standard for the Labelling of Prepackaged Foods, emphasizing its role in providing consumers with accurate and comprehensible information. By adhering to these labeling standards, the food industry contributes to consumer confidence, facilitates fair trade practices, and fosters global harmony in food product labeling.

Prevention is at the core of the Hazard Analysis and Critical Control Points (HACCP) system. This chapter unfolds the proactive approach of HACCP in identifying and mitigating hazards in the food production process. It highlights the collaborative nature of HACCP, emphasizing the importance of constant vigilance, regular monitoring, and continuous improvement to ensure the consistent production of safe and high-quality food.

Translating principles into practice is a pivotal step in ensuring food safety. This chapter provides a practical model for implementing food safety measures within a food company. It underscores the need for a holistic commitment to food safety at all organizational levels, offering guidance on developing and maintaining effective food safety management systems. By adopting such models, companies contribute to regulatory compliance, enhance consumer trust, and fortify the foundation of the entire food industry.

In conclusion, this exploration into food safety and quality is a call to action for the global food industry. From standardized analytical techniques to robust implementation models, each facet plays an integral role in the shared responsibility of delivering safe and high-quality food products. As we navigate these chapters, the overarching theme is clear – a commitment to excellence, transparency, and continuous improvement is the key to a resilient and trusted global food supply chain. The journey towards ensuring the safety and quality of our food is ongoing, requiring collaboration, innovation, and a steadfast dedication to the well-being of consumers worldwide.

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