

Chapter 5 : Effect of Processing on Food Quality

1. Definition of Quality According to ISO

Quality, as defined by the International Organization for Standardization (ISO), is "the set of properties and characteristics of a product or service that give it the ability to satisfy expressed or implicit needs." In the food sector, this definition takes on particular importance, as food is intended for the final consumer, who expects several types of "satisfaction" from it. Thus, food quality is a multidimensional concept, integrating not only safety, nutritional benefits, and sensory pleasure, but also practical usability, as well as more intangible aspects related to ethical values, product consistency over time, and its social or emotional image. Today, in light of evolving societal expectations—such as the demand for healthier, more sustainable, and more transparent food—it has become essential to understand that food quality is built around several complementary components, often schematized into 4 + 4 fundamental axes.

2. Types of Food Quality

a) Safety: Hygienic Quality

The first consumer requirement is the safety of the food, meaning its harmlessness. A food product must be free from hazards that could harm health. These hazards can be microbiological (e.g., salmonella, listeria, hepatitis A virus), chemical (e.g., pesticide residues, heavy metals, mycotoxins), physical (e.g., foreign objects like glass or metal), or related to common food components in excessive amounts (such as excess salt or saturated fats) or unsuitable for certain populations (e.g., lactose for lactose-intolerant individuals, allergens such as peanuts). Managing this hygienic quality today relies on rigorous systems like HACCP (Hazard Analysis Critical Control Point), which is mandated by international regulations and reinforced by the "Hygiene Package" standards in Europe. The stakes are such that product safety is now considered a fundamental right for consumers.

b) Health: Nutritional Quality

The second component is nutritional quality. The consumer seeks foods that are not only safe but also beneficial to health. This involves a balanced intake of macronutrients (proteins, carbohydrates, fats) and micronutrients (vitamins, minerals), as well as bioactive compounds (fibers, polyphenols, omega-3s, probiotics) known for their preventive role against certain

chronic diseases (diabetes, obesity, cardiovascular diseases). In light of current challenges related to urbanization, an aging population, and the prevalence of non-communicable diseases, the food industry strives to reformulate its products to reduce, for example, salt, added sugar, and trans fats, while enriching some foods with protective nutrients. However, it is important to remember that nutritional balance does not depend on a single food but on the overall diet over an extended period: no food is perfect on its own. Therefore, dietary diversity remains the key to health. This nutritional quality is often invisible to the consumer, who must rely on regulations and nutritional labeling.

c) Flavor: Organoleptic or Hedonic Quality

Flavor, or organoleptic quality, represents the sensory dimension of food. It concerns not only taste but also smell, visual appearance, texture, and sometimes even sound (such as the crunch of a biscuit). Food pleasure is a crucial driver of consumer choice. Recent studies show that sensory satisfaction directly influences consumption, sometimes at the expense of nutritional balance (e.g., preferences for foods high in fats and sugars). Sensory analyses, conducted by tasting panels, help to objectify these criteria in the laboratory. However, the emotional and social dimension must not be overlooked: the same food can be perceived differently depending on the consumption context, atmosphere, or the memories it evokes.

d) Service: Usability Quality

Ease of use has become an essential criterion in modern lifestyles, characterized by a lack of time. A food product, even if it is healthy and flavorful, must be practical: easy to store, prepare, preserve, and consume. The food industry is constantly innovating in packaging technologies (e.g., resealable packaging, single portions, microwaveable solutions) to meet these demands. Moreover, financial accessibility remains crucial: a good product must be affordable for a broad segment of the population. The quality-to-price ratio is a key determinant, even though it is sometimes biased by psychological perceptions ("the more expensive, the better"). Thus, service quality includes convenience, product durability, and economic accessibility.

After these first four fundamental components (Safety, Health, Flavor, Service—the "4S"), other more intangible but equally important dimensions come into play:

e) Regularity: Consistency of Quality

Regularity is essential for customer loyalty. Consumers expect a product to maintain the same

quality over time, without surprises, even positive ones. Significant variability damages trust and harms the brand. Manufacturers have developed quality assurance systems, standardization, and process monitoring to guarantee this stability (e.g., wine blending to achieve a consistent taste, homogenization of dairy products). However, this pursuit of regularity sometimes leads to a loss of the natural richness of products, which historically varied according to seasons, regions, and years.

f) Dream: Emotional and Imaginary Quality

Food is not just a source of nutrients; it also carries dreams, emotions, and cultural representations. Agri-food marketing widely exploits this dimension by emphasizing authenticity, naturalness, tradition, terroir, or personal well-being (e.g., advertisements featuring rural landscapes, "grandmother's recipes," or the image of healthy and ethical organic food). This "transferred quality" strongly influences the purchase decision and enhances the sensory experience, even though, objectively, the product remains unchanged.

g) Technology: Suitability for Processing and Distribution

Technological quality refers to the properties that facilitate the industrial transformation and distribution of the product. It primarily concerns professionals (processors, logisticians, distributors). Examples include the bakeability of flour, water retention capacity of meat destined for charcuterie, packaging resistance, or the shelf life of yogurt on shelves. These qualities ensure the efficiency and profitability of the agri-food chain. With the globalization of trade, they are becoming increasingly important because they optimize transportation and preservation over long distances.

h) Ethics: Social and Environmental Responsibility

Finally, more and more consumers demand that food products adhere to ethical principles: respect for producers (fair trade), environmental protection (organic farming, short supply chains), animal welfare (free-range farming), or reduced climate impact. Labels, certifications, and ethical standards (e.g., Fairtrade, Rainforest Alliance, organic labels) are becoming differentiating criteria and reinforce the civic engagement of consumers.

3. Effects of Processing on the Nutritional Quality of Foods

Food processing can either improve or deteriorate its nutritional value. Simple domestic preparation methods inevitably lead to the degradation of plant cells, resulting in a partial loss of essential vitamins and minerals. However, by adopting

appropriate processing techniques and consuming a variety of processed foods, it is possible to incorporate these products beneficially into a balanced diet. Unlike traditional methods, the food industry uses rapid processing techniques that minimize nutrient loss. Some treatments even enrich food with beneficial compounds, such as the increased lycopene content in cooked tomatoes, or eliminate undesirable elements, like lectins in legumes.

3.1. Effects on Vitamins and Minerals

Vitamins, of which there are thirteen, are essential to the body in small amounts. Four of them are fat-soluble (A, D, E, and K), while the other nine are water-soluble (vitamins C and the B vitamins). No single food contains all the vitamins, highlighting the importance of a varied diet. Processing affects vitamins in varying degrees: water-soluble vitamins, in particular, are more susceptible to losses during thermal treatments. However, emerging "non-thermal" processes, such as ohmic heating or ultra-high pressure treatment, help preserve vitamins by using lower temperatures and shorter processing times. Interestingly, some processed products may contain more vitamins than their fresh counterparts. For example, frozen vegetables, harvested shortly before freezing, retain higher vitamin C levels than vegetables stored in the refrigerator for several days.

Regarding minerals, which are also essential in small amounts, processing can have positive effects. For example, fermentation of whole grains degrades phytates, compounds that inhibit the absorption of iron and zinc, thus increasing the bioavailability of these minerals.

Moreover, food fortification is a common public health strategy: breakfast cereals, enriched with iron, now serve as a significant source of this mineral, especially for young women whose consumption of red meat (rich in bioavailable iron) has decreased. In some countries, flour is also enriched with folic acid to prevent neural tube defects in newborns.

3.2. Effects on Carbohydrates and Fiber

Regarding carbohydrates, moderate thermal treatments, such as UHT sterilization, cause little degradation. However, certain molecular transformations of sugars can occur, altering their digestibility. This can be beneficial, such as when the content of indigestible oligosaccharides (like stachyose and raffinose) is reduced, which are responsible for flatulence after consuming legumes.

Many studies currently focus on the impact of processing on the solubility and digestibility of

certain fibers and starches, particularly resistant starch. Reduced digestibility can provide metabolic advantages: slowly digesting carbohydrates help limit rapid increases in blood sugar and insulin levels after a meal, reducing the risk of developing insulin resistance, a precursor to type 2 diabetes. Additionally, certain processes like cooking-extrusion increase the solubility of dietary fibers. Soluble fibers, such as β -glucans, contribute to lowering blood cholesterol, reducing the risk of cardiovascular diseases.

3.3. Effects on Fats and Proteins

Fats are generally stable during food processing. However, unsaturated fatty acids are sensitive to oxidation and may become rancid during storage. To counteract this, techniques such as modified atmosphere packaging, the addition of antioxidants, or aseptic packaging are widely used, thus prolonging shelf life.

Proteins, on the other hand, often undergo denaturation due to heat, which can alter the texture of food but improve digestibility. Furthermore, modern processes such as high pressure, electric fields, or irradiation can act on certain food allergens. For example, cooking eggs denatures avidin, releasing biotin, an essential vitamin that is initially blocked by this protein in raw eggs. Therefore, processing plays a key role in enhancing the nutritional value of food proteins.

4. Main Benefits of Processed Foods

Food processing provides numerous advantages, including improved taste, nutritional quality, safety, and convenience, while also contributing to the reduction of food waste.

4.1. Improvement of Palatability and Sensory Qualities

Processing is essential for making most foods edible and appealing. While some transformations are simple — such as peeling a banana or cooking a potato — others are more complex, like processing wheat, which must be harvested, cleaned, ground into flour, and then turned into bread or pasta. Many processing techniques directly enhance the organoleptic qualities of food: for example, cooking canned beans gives them a creamy texture that is highly sought after. Similarly, extruded and puffed products, like breakfast cereals or chips, require modern equipment to be produced on a large scale.

4.2. Preservation and Enhancement of Nutritional Quality

Food processing not only helps preserve nutrients, such as through freezing, but also increases their bioavailability. For example, cooking and canning tomatoes enhance the absorption of lycopene, a potent antioxidant. Likewise, careful processing of cocoa preserves its flavonoids, compounds associated with better cardiovascular health and a reduced risk of certain cancers. Today, research is focused on how processing can optimize nutrient digestibility. For instance, milk homogenization, by reducing the size of fat droplets and proteins, seems to improve the digestibility of the final product. Additionally, manipulating the structure of triglycerides could positively affect fat absorption, thus contributing to the prevention of cardiovascular diseases.

4.3. Safety

Numerous processing techniques ensure food safety by reducing the number of harmful bacteria that can cause illnesses, such as milk pasteurization. Drying, salting, and smoking reduce water activity (available water for bacterial growth) and alter the pH of foods, limiting the growth of pathogenic microorganisms and spoilage, while also delaying enzymatic reactions. Other techniques, such as canning, pasteurization, and UHT treatment, directly destroy bacteria through heat.

Another advantage of processing is the destruction of antinutritional factors. For example, cooking destroys antiproteins like trypsin inhibitors found in peas, beans, or potatoes. These small globular proteins inhibit the action of human digestive enzymes (trypsin and chymotrypsin), which are essential for digesting dietary proteins. If they remain present, they reduce the nutritional value of foods and can be toxic in high amounts. Prolonged cooking also helps eliminate harmful lectins found in some legumes, such as red beans, which can cause red blood cell agglutination and severe gastroenteritis if not inactivated.

4.4. Storage, Convenience, and Choice

Food processing significantly extends the shelf life of perishable foods such as meat, milk, and their derivatives. For example, modified atmosphere packaging helps preserve the freshness of fruits and vegetables, reducing the frequency of grocery shopping and

minimizing household food waste. Additionally, processing makes it possible to consume out-of-season foods or those produced in other regions of the world, increasing variety and choice for consumers.

Techniques like freezing, dehydration, and canning also allow food to be stored for long periods without major loss of nutritional or sensory quality. Convenience is another major benefit: processed foods save time in the kitchen and cater to modern lifestyles. Frozen vegetables, ready-to-eat meals, and balanced snacks make meal preparation quicker and more accessible, without sacrificing nutritional quality when chosen carefully.

4.5. Reduction of Food Losses

Food processing plays a key role in reducing food waste throughout the supply chain. Fruits and vegetables that would otherwise be discarded due to their imperfect appearance can be transformed into purees, juices, or other products. Similarly, surplus agricultural production can be processed and stored in a stable form for later use. This not only contributes to global food security but also ensures better utilization of agricultural resources, reducing the environmental impact of food production.

5. Disadvantages of Food Processing

5.1. Nutrient Loss

Some processing techniques can lead to the degradation or partial loss of nutrients naturally present in foods. For example, pasteurization, prolonged cooking, or blanching before freezing can reduce the content of heat-sensitive vitamins such as vitamin C or certain B vitamins. Similarly, cereal refining processes remove a large portion of the fiber, minerals, and vitamins contained in the grain's husk, thus reducing the nutritional value of the final product.

5.2. Addition of Potentially Undesirable Substances

Many processed foods contain additives such as preservatives, colorants, artificial flavors, and texturizing agents. While most are considered safe within regulated limits, their excessive consumption has sometimes been associated with adverse health effects.

Furthermore, some ultra-processed foods are high in added sugars, salt, and saturated or trans

fats, which are known to increase the risk of chronic diseases such as obesity, type 2 diabetes, high blood pressure, and cardiovascular diseases.

5.3. Formation of Harmful Compounds

Certain processing methods, especially high-temperature treatments (frying, grilling, barbecuing), can lead to the formation of undesirable chemical compounds, such as acrylamide, polycyclic aromatic hydrocarbons (PAHs), and heterocyclic amines. These substances are suspected to be potentially carcinogenic or mutagenic according to several experimental and epidemiological studies.

5.4. Modification of Food Structure

Processing can also alter the food matrix — that is, the natural physical and chemical organization of foods. This influences the speed of digestion and nutrient absorption. For example, highly processed foods may be digested quickly, leading to higher blood sugar spikes and less satiety, which can promote overeating.

5.5. Environmental Impact

Industrial food processing requires energy, water, and additional resources for manufacturing, packaging, transportation, and storage. It also generates waste (plastic packaging, greenhouse gas emissions, industrial by-products), contributing to the ecological footprint of the food sector. Promoting minimally processed foods and eco-friendly packaging represents a key challenge to reducing environmental impact.

6. Conclusion

Food processing offers numerous benefits, including improved food safety, product preservation, expanded choice, and sometimes even enhanced nutritional value. However, it can also lead to nutrient losses, the formation of undesirable substances, and have adverse effects on health and the environment when taken to extremes.

It is therefore crucial to encourage processing practices that respect nutritional quality, limit excessive processing, and promote a balanced diet incorporating minimally or moderately processed foods. The role of an informed consumer is also vital: reading labels, prioritizing

quality products, and diversifying one's diet are simple yet effective strategies to maximize the benefits of processing while minimizing its risks.

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