

Food Preservation Concerns of Functional Foods

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ABSTRACT

Food preservation represents a critical public health intervention essential for safeguarding consumer wellbeing. This multifaceted approach encompasses adherence to stringent hygiene protocols throughout manufacturing processes and seeks to ensure population health security through the provision of microbiologically safe, organoleptically acceptable, and nutritionally preserved food products. The

defining elements of food safety are as follows: the quality of raw materials entering the manufacturing process, the food production process, storage and transportation of food, and the conditions of food marketing. The current handling for food denotes to super critical fluid technology, membrane technology and biotechnology applications for obtaining functional food, “all natural” augmented foods. Nowadays in modern world food processing has gain its importance in all food related industries as a vital phenomenon. From this perspective, processed foods have several advantages: the susceptibility to deterioration of processed food is less compared to fresh foods; the preservation period is longer without any change in nutritional or taste qualities; and they exhibit better transport resistance from production units to consumers. Without adequate processing interventions, food products exhibit accelerated deterioration due to multiple contributing factors, including endogenous enzymatic activity, water activity levels, microbial proliferation, thermal fluctuations, and additional environmental variables.

Keywords: Functional foods, Food preservation, Bioactive compounds, Shelf life, Stability

Introduction

A preserved food considered stabilized in accordance to quality and safety. Functional food is a type of food that delivers healthy benefits, as defined by the International Food Information Council (IFIC). Any food that provides beneficial effects to bodily target functions and is helpful in reducing risks for diseases further basic nutrition considered as functional food

(Giacco et al., 2012; Bonciu, 2018).The European Union initiative "Functional Food Science in Europe" established a comprehensive definition of functional foods as products that confer health benefits through targeted physiological mechanisms, specifically enhancing wellbeing and mitigating disease risk factors beyond basic nutritional requirements. These functional foods maintain their conventional food matrix while demonstrating scientifically validated beneficial effects through regular dietary consumption. Importantly, functional foods are distinguished from pharmaceutical supplements by their integration into standard dietary patterns rather than being consumed as isolated capsules or tablets.”(Hasler et al., 2009).Essentially, functional foods are health supplements containing various components beneficial for the body and preventive measures against illnesses (Hamdan et al., 2018).As regulatory concerns, the identification of the active ingredients in functional food is accountable for projected health benefits (Passi, 2017).Functional foods create a line between medicine and food(Bhardwaj& Khanna, 2013).Functional foods, due to their possession of physiologically active constituents, have been described as delivering health effects. Daily consumption of functional foods provides nutrients in sufficient amounts and is also beneficial in improving gastrointestinal tract function, lowering cholesterol, stimulating the immune system, reducing oxidative stress, and lowering the risks of cardiovascular diseases, neurodegenerative diseases, cancers, and metabolic syndrome (Kasemap, 2018).

Functional classification of Functional foods with examples:

Functional foods have been developed across virtually all food categories, though their market penetration remains variable among different industry segments. The Consumers' preferences may vary in the selection of functional foods in the market. Functional foods are in the dairy, soft drinks, baby food, confectionery and bakery

markets (Kotilainen et al., 2006; Menrad, 2003). Current literature presents multiple classification systems for functional foods. Research by Kotilainen et al. (2006), Sloan (2000), and Spence (2006) has proposed a product-based taxonomic framework for categorizing these foods:

- Nutrient-fortified food, also known as labeled fortified items. For example, fortification of food items with vitamin E, vitamin C, Calcium, folic acid, and zinc;
- New added nutrients or ingredients normally not present in such required quantity, known as labeled enriched products, for example, prebiotics and probiotics.
- Replaced ingredients in foods, also known as labeled altered products, deleterious ingredients replaced, removed, or reduced with another beneficial ingredient

Foods with naturally enhanced ingredients, also known as labeled enhanced foods, the addition of omega-3 in eggs. According to the American Dietetic Association, Functional foods include infant foods, fortified foods, gluten-free foods, dietary supplements, lactose-free foods, and weight loss foods (Bigliardi & Galati, 2013).

Based on the functions of functional foods, these could be classified as:

- Life-improving foods like pre-and probiotics.
- Health risk-reducing foods like high blood pressure and cholesterol.
- Life making easier foods like gluten and lactose-free products.

Functional Food categories

Conventional foods (whole foods)

Special dietary Foods

Medical foods

Modified foods

Enriched

Fortified

Enhanced

Functional Food examples

Garlic

Nuts

Tomatoes

Specialized infant formulations, hypoallergenic products such as gluten-free and lactose-free alternatives, and weight management foods designed for therapeutic dietary interventions.

Phenylketonuria (PKU) formulas free of phenylalanine

Enriched

Folate-enriched breads

#Contemporary functional food products include calcium-fortified orange juice, iodized salt, specialty teas, probiotic yogurt, nutritional snacks, energy bars, and enhanced bottled water. These products are formulated with various bioactive compounds, including lutein, omega-3 fatty acids from fish oils, ginkgo biloba extract, St. John's wort, saw palmetto extract, and specific amino acid complexes.

History of Functional Foods:

Japan pioneered the conceptualization of functional foods in the mid-1980s, defining them as processed food products that provide physiological benefits beyond conventional nutritional value through targeted body functions. Subsequently, Japan became the first nation to establish comprehensive regulatory frameworks for functional food approval through the Food for Specific Health Use (FOSHU) classification system, administered by the Japanese Ministry of Health and Welfare (Kersevani et al., 2017).

Functional foods' objectives:

Functional foods have several key purposes: improving general health through prebiotic and probiotic components, providing therapeutic benefits for various medical conditions, and reducing the risk of developing multiple diseases (Mark-Herbert, 2004, Szakaly, et al., 2012)). Recently, functional food allows for increasing efficiency of absorptive power of galactosamine-receptor in antitumour drugs otherwise decomposing to uracil, rich in radical oxygen species that increasing probability of metastasis (Zhong et al., 2025).

Preservatives/antimicrobial agents

The preservatives are compounds responsible for preventing food spoilage, exhibiting antimicrobial activities and aiding in the degradation of food products through both enzymatic and non-enzymatic processes. Food safety and quality maintenance are achieved through strategic implementation of antimicrobial preservation systems. Selection criteria for appropriate preservative compounds are primarily determined by pH compatibility and solubility characteristics of the target food matrix. While antimicrobial agents effectively extend product shelf life, excessive concentrations can compromise organoleptic properties, manifesting as altered taste profiles, color degradation, off-odor development, modified solubility parameters, and rheological changes that may negatively impact consumer acceptance and nutritional quality.

(Msagati TA, 2012). Different food industries use various types of preservatives according to their needs for inhibiting browning, especially non-enzymatic browning, and for reversible protein cleavage. The meat industries used mostly nitrate and nitrite salts of potassium and sodium for the preservation of treated meat and sausages. For the molds prevention on breads and bakery items, acetates of calcium, sodium, and potassium, and propionic acid, benzoate, and glycerol esters were used (Belitz et al., 2009). The consumption of antibiotic-treated foods may cause an increase in consumer sensitivity and may lead to the development of antibiotic-resistant microorganisms (Damoradan et al., 2017). Similarly, in the case of yoghurt and cheese-producing industries, benzoates, Lactobacillus, and sorbates are used as preservatives to prevent unwanted fungi, yeasts, and bacteria, thereby helping to maintain and improve nutritional qualities (Martins et al., 2019).

Methods of Food Preservation:

Conventional methods:

The well-known conventional methods of food preservation are pasteurization, sterilization and refrigeration and many others (Hamoud-Agha&Allaf, 2009). In recent times, it has become necessary to replace traditional food processing methods with alternative methods (Bonciu, 2018).

Modern methods:

Contemporary food processing paradigms increasingly necessitate the integration of alternative preservation technologies to supplement conventional methodologies. A primary advantage of these emerging technologies lies in their enhanced energy efficiency compared to traditional thermal processing methods. Advanced alternative approaches harness mechanical, photonic, electromagnetic, and electrical energy sources to accelerate biochemical reactions while maintaining product integrity. Ultraviolet (UV) irradiation, high-pressure processing (HPP), pulsed electric field (PEF) technology, and membrane filtration systems represent prominent examples of alternative preservation technologies gaining significant commercial traction due to their ability to extend shelf life while preserving nutritional and sensory attributes.(Rodriguez-Gonzalez et al., 2016). The momentum, electromagnetic, heat, and photon transfer are the primary energy transfer modes in these technologies, serving as unit operations. These modern food technologies delimit modern food manufacturing. There are three major aims of modern food processing technologies: safe food manufacturing (chemically and microbiologically); convenient food form (easy to use), and high-quality food (color, flavor, texture). Food safety has become the top priority for many governments and countries. With globalization, the food safety issues and overall demand have enhanced, lead to more and more food manufacturing (Bonciu, 2018).Nanotechnology is the advanced form of processing and preservation. The applications of nanomaterials are increasing in various sectors, including food, agriculture, clothing, cosmetics, medicine, and public health, due to their ability to enhance solubility and bioavailability, as well as protect bioactive ingredients during processing and storage (Pathakoti et al., 2017; Fu, 2014; Hu et al., 2017-20).Due to their antimicrobial capability and outstanding physicochemical nature, they're extensively used for crop protection, food safety and preservation, water treatment, and against pathogenic microbes (Baranwal et al., 2018).Many reports have revealed that nanomaterials can help improve food safety by augmenting the food packaging efficacy, nutritional value, shelf life, and quality without any change in taste and physical characteristics(Das et al., 2018, He& Hwang, 2016).The role of nanotechniquesin the nutraceutical and functional food sectors is obvious and indispensable(Bajpai et al., 2018).The most commonly used natural flavor complexes are essential oils, which are low-molecular-weight constituents received from plants through various processes, including cold pressing, distillation, and extraction. Essential oils are also known as volatile oils and ethereal oils, having a specific aroma. These oils are mainly derived from various plant parts, including flowers, seeds, twigs, buds, leaves, herbs, wood, bark, roots, and fruits. They can be extracted by fermentation, expression, steam distillation, and effleurage. The most common method is steam distillation for the marketable manufacture of essential oils (Ameh, 2016; Van de Braak et al., 1999). Citrus essential oil (EOs) is another

alternative natural method to commonly use chemical preservatives and other antioxidants like benzoates, sodium nitrates, and nitrites. In recent times, EOs have garnered pronounced attention as natural preservative agents in many food and packaging industries due to the demand for food product safety and consumer concerns (Mahato et al., 2019).

Food Safety Perspectives in relation to preservation:

In any case, inventions in the form of new products and procedures are renowned as a significant tool for the food industry to attract attention from competitors and to justify consumers' expectations (Menrad, 2004). Over the past decade, consumer preferences have undergone substantial transformation within the food sector, with increasing recognition that functional foods constitute integral components of preventive healthcare strategies (Mollet & Rowland 2002, Hobbs & Young 2000). A major consumer concern is choosing healthy foods, and it is an imperative agenda for everyone (Salleh et al., 2015). Food safety represents a fundamental public health priority worldwide. Safe food is defined as products that pose no harm to consumers throughout manufacturing processes and consumption, which constitutes the primary objective of food safety systems. Achieving food safety requires protection against three categories of hazards—biological, physical, and chemical—across all stages of production, handling, and distribution. (Bajpai et al., 2018). The term "organic food" has gained popularity among consumers in recent years due to its prolonged shelf life, additive-free nature, and better taste. A new ozone-based technology for food preservation is more beneficial for producers and consumers as well (Pandiselvam et al., 2019). Modern advances in nanotechnology have transformed the food industry with numerous applications in food handling, preservation, and safety, while maintaining nutraceutical values, extending shelf life, and reducing packaging waste. Food safety has become a critical concern due to rapid evolution in regulatory frameworks and industry practices. (Kersevani et al., 2017). Generally, food safety is a major public health concern worldwide (Pal, 2017). Food safety is achieved when products present no adverse health effects to consumers throughout the production process and consumption phase, representing the fundamental goal of food safety protocols. (Bajpai et al., 2018). Ensuring food safety requires protection against three primary hazard categories—biological, physical, and chemical—throughout all stages of production, handling, and distribution. (Vasilaki et al., 2019). The term "organic food" has gained popularity among consumers in recent years due to its prolonged shelf life, additive-free nature, and better taste. A new ozone-based technology for food preservation is more beneficial for producers and consumers as well (Pandiselvam et al., 2019). Contemporary consumer trends demonstrate a pronounced preference for products perceived as natural in origin (Rozin, 2005). The incorporation of novel ingredients or additives may potentially compromise consumer perceptions of product naturalness (Lahteenmaki, 2013). Research by Verbeke and colleagues has identified that the nature of anticipated health benefits and geographic cultural context represent primary determinants influencing consumer acceptance and purchasing decisions regarding functional food products. (Pieniak et al., 2009). Yeast and moulds can grow in all food items, capable of producing toxins through various enzymes, such as proteases and lipases, causing bad flavor and discoloration. From a food safety perspective, a mould's important feature is its ability to produce

mycotoxins. Similarly, fungi are the main source of spoilage in bakery products. Hence, natural preservatives containing bakery items increasing demand (Lopez-Malo et al., 2005). The "Clean Label" trend, which emphasizes natural ingredients and includes claims such as "no preservatives," "no artificial colors," "no additives," and "no artificial flavors," has evolved into the "Clear Label" concept that prioritizes transparency in food manufacturing and ingredient disclosure (Bonci, 2018).

Functional foods from consumers' point of view:

Functional foods are designed to provide people with high-quality food for a better quality of life (Ameh & Obodozie-Ofoegbu, 2016; Landstrom et al., 2009). Consumer attitudes toward functional foods are complex and determined by multiple variables, including demographic and socioeconomic factors, psychological and behavioral elements, social influences, and product-specific considerations such as health claims, safety profiles, organoleptic properties, cost, accessibility, and environmental impact (Ponte et al., 2025). Research indicates that the American people are well aware of functional foods and want to include these foods in their daily diet (Khan et al., 2019). Danish consumers demonstrate resistance toward engineered food products, perceiving these items as lacking naturalness and purity compared to traditional food offerings. However, in Finland, the situation is different because consumers have shown a well-received response (Gineikiene et al., 2017; Wohlers 2017). Among the organoleptic properties, taste is the most important for the consumer to make a better choice of food. Hence, after the fortification of food with various ingredients, the taste of functional food remains the same (Khan et al., 2019). Research findings demonstrate that female consumers exhibit a greater preference for functional food products than their male counterparts (Varela-Candamio et al., 2018). In seven years time, the changes in functional food consumption equalize in contribution to gender, especially in Latin American countries (Molina-Montero et al., 2025). UK research indicates that individuals with higher educational attainment demonstrate increased adoption of functional foods, primarily targeting weight management or cholesterol reduction (Gaykema et al., 2017). But in 2024 in United Kingdom the interesting of fortified food increased generally with all group especially South Wales and besides weight management especially young women and diabetic patient (Embling et al., 2024).

Natural preservatives in comparison to synthetic preservatives:

Currently, a strong debate exists regarding the safety aspects of synthetic preservatives, which are considered a concern due to their carcinogenic and teratogenic characteristics and toxicity. Due to these reasons, the behavior of consumers shifts towards natural and more acceptable preservatives (Rasooli, 2007). The sulphide content of preservatives and its potential danger effects on human health are increasing the demand for natural preservatives globally (Ferreira et al., 2018). Natural products are increasingly preferred as preservatives due to two fundamental characteristics: their inherent preservation capacity and bioactive properties. The potent bioactivity of these natural compounds stems from bioactive molecules, particularly phenolic compounds, which exhibit significant antioxidant and antimicrobial activities that support their efficacy as food preservatives (Carocho & Ferreira 2013). There are many studies explaining that hundreds of plants are rich in polyphenols, which have preservative abilities, and can

be used after extraction and purification (Ferreira et al., 2018). Nicin and lysozymes are natural substances that have been evaluated as food preservatives added to edible food, safe for humans (Nguyen et al., 2008). The strong antimicrobial spices include cinnamon, mustard, allspice, and vanillin, as indicated through experiments. Among herbs, the most antimicrobial herbs are oregano, sage, basil, rosemary, and thyme. The limited antimicrobial showing herbs and spices are black pepper, anise, red pepper, anise, cardamom, coriander, celery seed, cumin, chili powder, dill, ginger, curry powder, mace, marjoram, juniper oil, mint, paprika, nutmeg, white pepper, tarragon and spearmint (Davidson & Naidu 2000). Yeast and moulds have the ability to grow in all food items, capable of producing toxins through various enzymes, such as proteases and lipases, causing bad flavor and discoloration. From a food safety perspective mould's important feature is its ability to produce mycotoxins. Fungal contamination represents the primary cause of bakery product spoilage. Consequently, consumer demand for bakery products containing natural preservatives continues to increase (Lopez-Malo et al., 2005).

Conclusion & Future Perspective:

It is concluded that foods preserved with natural preservatives have gained more attraction because of consumer awareness and concerns regarding synthetic chemical preservatives and additives. This has directed researchers and food manufacturers to look for natural preservatives and additives.

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