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Editorial: Functional foods processing and preservation

1. Introduction

Functional foods have a nutritive value and appearance similar to conventional foods, but they bring additional health-promoting effects and/or disease-preventing capabilities when consumed as part of a varied daily diet. These can occur naturally or be developed through processing or agro-biotechnological strategies. However, modified or not, they must always be safe, without any consideration of a trade-off between health benefit and health risk (Pinela et al., 2016). Nowadays, processing and preserving functional foods, whether solid or liquid, is a major scientific challenge since the factors involved can lead to the degradation of micronutrients and bioactive compounds and affect physicochemical parameters.

Different technologies have emerged in the food sector with the potential to preserve quality attributes more effectively than conventionally used thermal processing methods. High pressure, cold plasma, pulsed light, sonication, ozonation, vacuum impregnation, and electrotechnologies are good examples of nonthermal alternatives potentially capable of meeting consumer demands for high quality and shelf-stable functional foods (Pinela & Ferreira, 2017). Biological approaches involving enzymatic treatments, fermentation, and biopreservation, and recent 3D-printing techniques have also been explored (Castro et al., 2017; Tomašević et al., 2021).

At the moment there is a need to understand and elucidate the effects of processing on the functional food constituents responsible for their biological and technological properties, as well as on microorganisms and enzymes related to degradation phenomena and safety issues. Some of these innovative technologies can also be used in the extraction of valuable compounds from food by-products, a trend driven by growing industrial demand for functional ingredients and the need towards resource-use efficiency. Novel techniques for stabilization and controlled release of bioactive compounds in food matrices have also been in the research spotlight (Dias et al., 2015; Tchabo et al., 2022).

This special issue covers recent developments on the effects of different processing and preservation methods on nutritional, chemical, microbiological, and bioactive properties of different functional foods, which have been developed to attend the growing consumer demand for high quality and safe products with improved nutritional and heat-proofing effects, as well as nutritional needs of specific population groups. Chemical and bioactive properties of natural products are also discussed, as well as the development of functional ingredients for application in the food industry and related sectors.

2. Functional foods processing and preservation methods

Pasteurization is one of the most effective thermal methods for microbial elimination and food shelf-life extension. Raji et al. (2022) produced pasteurized mixed fruit juices from pineapple and underutilized bitter orange without adding synthetic preservatives and evaluated their quality during storage at room temperature for 6 months. Juice containing 25% of bitter orange and 75% pineapple was preferred by panelists, had high antioxidant activity, better keeping quality, and acceptable quality up to 4 months. In turn, Ali and Wang (2021) investigated the effect of pasteurization on the microbial transglutaminase (mTGase) cross-linking function aiming at milk fat globule membrane (MFGM) isolation. The composition of buttermilk and their isolates was enhanced by the mTGase enriched by initial pasteurization. However, pasteurization had an adverse effect on the obtained MFGM proportion, and mTGase reduced the κ-casein association with MFGM.

Tanguler and Sener (2022) developed a new functional fermented beverage by combining juice from the underutilized grape *Tarsus beyazi* and metabolic products of *Williopsis saturnus*, a yeast that can convert alcohols to esters. Fermentation performed with yeast inoculated at 1×10^6 and 1×10^7 cells/mL for 15 days at 10 °C stood out based on general and sensory analyses. As observed for these naturally flavored beverages, there was also a decrease in total phenolic and flavonoid content and antioxidant activity in carbonated beverages with increasing fermentation time. In another work, gluten-free fermented soup powders suitable for celiac patients or gluten sensitive individuals were developed by Taşkın and Savlak (2022) using drum drying. These sensorially accepted functional foods contained mung bean (*Vigna radiata* L.) and were rich in protein and dietary fiber and showed bioactive properties. Refractance window is another food processing method which uses conduction and radiation as heat transfer mechanisms to provide a fast drying. Tontul et al. (2021) applied this technology to dry kefir, a popular fermented product with health-promoting effects. During 90 days of storage at 4 °C, the obtained kefir powder showed good flowability and low cohesiveness and much better wettability, hygroscopicity and solubility than freeze-dried kefir powder. Furthermore, refractance window drying took less than 52 min, while freeze-drying took 24 h.

3. Food products added with bioactive plant extracts

The formulation of foods with natural bioactive ingredients has been a practice used to improve their functional characteristics and shelf-life. Parafati et al. (2021) produced burger patties functionalized with prickly pear extract, which was incorporated directly and encapsulated

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in alginate beads. The texture of the cooked burgers was not affected by the extract, which preserved the surface meat color, and the samples with encapsulated extract showed better lipid oxidation inhibition and antioxidant capacity. The burger patties added with extract also had good sensory acceptance. Thus, prickly pear extract has emerged as a promising natural preservative for these food products. Ayaseh et al. (2022) investigated the effect of beetroot extract and ε-polylysine as nitrite substitutes in vacuum packaged frankfurter-type sausages during 30 days of storage at 4 °C. ε-Polylysine is a thermostable peptide widely used in meat products. The combination of these substances had no significant effects on water activity and proximate composition of frankfurter-type sausages, prevented the pH increase and maintained the pink color and texture consistency. Furthermore, the organoleptic acceptability and stability of these sausages were equal to or even higher than those of control samples. Still on meat products, Sagar et al. (2022) evaluated the impact of edible coating made from essential oil nanoemulsions on quality attributes of chicken fingers during storage at 4 °C. Essential oils from cinnamon (*Cinnamomum zeylanicum*), thyme (*Thymus vulgaris*), and clove (*Syzygium aromaticum*) were used to prepare the nanoemulsions, which showed good antimicrobial and antioxidant activities. The tested edible coating allowed maintaining quality attributes and extending the chicken fingers shelf-life, thus emerging as possible alternatives to synthetic antioxidant and antimicrobial agents.

4. Functional ingredients for the food and nutraceutical industry

The potential of plant species to develop functional food ingredients is also discussed in this special issue. Tripathy et al. (2022) reviewed the chemical characteristics of the edible medicinal plant *Centella asiatica* (L.) Urb. that potentiate its use in the development of functional foods and nutraceuticals. Methods for extraction and analysis of its active constituents were also described. The chemical composition and biological activity of wild and commercial *Moringa oleifera* Lam. leaves was covered by Fernandes et al. (2021). This edible plant has been used to fight malnutrition in developing countries and has great potential to be used as an ingredient for foods, nutraceuticals, and dietary supplements. The authors demonstrated that commercially acquired *M. oleifera* samples had better nutritional quality than those collected from the wild, which sparked interest in studying the processing methods used by local populations in Guinea-Bissau. In a different study, Çetin-Babaoğlu et al. (2021) produced low-glycemic index snacks from pigmented maize varieties through a two-stage baking process. The blue corn-produced snacks stood out as low-glycemic index foods and contained more anthocyanins than those made from yellow or red maize. Thus, authors concluded that anthocyanins may be more effective in reducing the glycemic index than dietary fibers or total phenolics.

Rajakaruna et al. (2022) demonstrated that alkaline green solvents as pressurized fluids in accelerated solvent extraction provide a good recovery of bioactive compounds from wild berries of *Vaccinium angustifolium* Benth., *Vaccinium vitis-idaea* L., and *Rosa canina* L. The obtained food-grade extracts were pointed out as candidate ingredients for the food and nutraceutical industry. A study on chemical and bioactivity analysis of wild asparagus (*Asparagus stipularis* Forssk.) roots and rhizomes was conducted by Adouni et al. (2022). The root infusion extract had high antioxidant activity and it was effectively loaded into poly(D,L-lactide-co-glycolide) (PLGA) nanoparticles, which can be used as an innovative delivery system in functional foods and dietary supplements. Furthermore, none of the studied samples were toxic to normal PLP2 cells. In the study by Ganeson et al. (2022), cinnamon oil compounds were encapsulated in gelatin-based food packaging films. This approach stabilized and strengthened the polymeric molecules of gelatin and ensured the retention and slow release of bioactive compounds to foods, thus contributing to extending its shelf-life. This biodegradable film was tested in wax apples (*Syzygium samarangense* L.) during 12 days of storage at 5 °C. The film with a 70:30 oil to surfactant (FME 70) ratio gave a better overall performance as compared to the control gelatin films.

Given the growing consumer demand for more bioaccessible protein supplements, Kumar et al. (2022) developed a functional protein hydrolysate from spent hen meat. The authors found that spray-dried flavourzyme catalyzed hydrolysates had more essential amino acids and greater bioaccessibility and antioxidant activity freeze-dried ones. In addition, flavourzyme hydrolyzed powders were more soluble than those hydrolyzed by alcalase. Thus, spray-dried spent hen hydrolysate powder developed using flavourzyme was incorporated at 10% in a whey protein supplement, which was sensory acceptable. In another work, Zhang, Zhao, et al. (2022) prepared antioxidant peptides and gelatins from skipjack tuna (*Katsuwonus pelamis*) skins using acid, enzyme, and hot-water methods. Gelatin obtained by the acid method maintained the main structure of type I collagen and its hydrolysate fraction (<3.5 kDa) was able to attenuate cell photoaging. Furthermore, different peptides were prepared from the hydrolysates for further investigation.

5. Biological and health-related effects of natural compounds

Polysaccharides are important bioactive constituents of mushrooms. Wang et al. (2022) found that *Agaricus blazei* Murill polysaccharides can protect against liver and lung damages in mice with zymosan-induced multiple organ dysfunction syndrome. These can attenuate functional impairments of these organs, alleviate oxidative stress, inhibit the activation of the NF-κB signaling pathway, and reduce the expression of inflammatory cytokines. The authors concluded that these effects may be related to the β-pyranose configuration with a triple-helical structure. According to Sun et al. (2022), polysaccharides from *Agrocybe cylindracea* residue can alleviate type 2-diabetes-induced liver and colon injuries by p38 MAPK signaling pathway. These compounds reduced oxidative stress and inflammatory response, restored lipid levels, and decreased liver and colon lesions in mice, thus having a protective effect on these organs. Therefore, *A. cylindracea* polysaccharides could be used in food supplements to decrease blood glucose and relieve type 2 diabetes mellitus.

Vitamin E is the most important fat-soluble antioxidant, which protects cell membranes and low-density lipoproteins from oxidative damage. According to Khallouki et al. (2022), the vitamin E components and its oxidation products constitute the so-called “vitaminEome”. The oxidation chemistry of this vitamin and the biological properties of the resulting oxidation product were discussed by the authors, as well as its therapeutic and chemopreventive potential with a particular focus on anti-inflammatory and cytotoxic properties. In a different study with cyanidin-3-*O*-arabinoside, Zhang, Yu, et al. (2022) observed that the cytotoxic activity of this anthocyanin on Caco-2 cells is attributed to the capacity to inhibit cell proliferation and induce apoptosis. Thus, the involvement of this apple polyphenol in the prevention of colon cancer was highlighted by the authors.

6. Conclusion

This special issue showed that functional foods are in the spotlight of many researchers worldwide, who have focused many efforts on their development, processing, and preservation using different methods and natural bioactive ingredients, as well as on the screening and discovery of new bioactive compounds and functional ingredients from various species (e.g., plants, mushrooms, fish, as well as by-products) for application in the food industry and related sectors. These findings highlight the importance of cutting-edge scientific research and innovative processes and technologies in the development of functional foods and ingredients and light up new directions for further research.

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