Development of a Special Nutritional Supplement Based on Cabbage Powder as the Main Ingredient

Xianghan Wu[2,#], Siyuan He[1,#], Yang Liu[1,#], Shunjun Zhang[3], Guangyao Guo[3], Zhonghua Li[1], Dan Li[1,*] , Linfang Mo[1,**], Jinxiu Wang[4,***]

[1]Navy Special Medical Center, Naval Medical University, Shanghai, 200433, China
[2]Naval Medical University, Shanghai, 200000, China
[3]Shanghai Xincheng Food Co., Ltd, Shanghai, 200000, China
[4]Naval medical service Department, Shanghai, 200000, China
[#]These authors have contributed equally to this work.

Abstract: Food materials such as cabbage have therapeutic effects for improving certain diseases. Through specific formulations and technologies like drying, concentration, and ultrafine grinding, a type of nutritional supplement based on cabbage powder as the main ingredient has been developed. These supplements are presented in convenient forms, such as fruit and vegetable slices, noodles, hawthorn cakes, or rice flour, catering to different functional needs. Testing has shown that these products meet relevant food hygiene standards and have a shelf life of over 12 months, rendering them a potential reference for developing functional foods.

1. Introduction

Today's society is rapidly advancing, but health issues have also arisen. Fortunately, public awareness of health is continuously improving, and the demand for health-related products is increasing. Diet and health have attracted unprecedented global attention, and functional foods, as an emerging food concept, are receiving increasing attention [1, 2]. A significant feature that distinguishes functional foods from ordinary foods is the presence of bioactive substances or functional ingredients that can improve or influence human health. Functional foods on the market mainly exist in the form of dairy products, bread, candy, and functional beverages [3]. Functional foods based on plant-derived active ingredients are known as plant-functional foods. Many plants' active ingredients, such as ginsenosides, wolfberry polysaccharides, proanthocyanidins, lycopene, tea polyphenols, and soy isoflavones, have been widely developed and applied [2]. This paper reviews a type of special nutritional supplement developed by our research team, which is based on cabbage powder as the main ingredient, along with related functional food materials, functions, processing techniques, effects, and development status. The aim is to provide references and a basis for further research and development of functional foods.

2. Overview of functional foods

According to China's national food safety standards, such as the Standard for the Use of Food Additives (GB 2760—2014), the Standard for the Use of Nutritional Fortification Substances in Foods (GB 14880—2012), and the 2012 version of the Adjustment Plan for the Scope of Health Food Functions, functional foods can be classified into four categories: (1) Health-enhancing types, such as improving immunity, alleviating physical fatigue, and improving sleep; (2) Risk-reduction types, such as assisting in lowering blood lipids, blood sugar, blood pressure, and weight loss; (3) Protection against external harmful factors, such as reducing radiation damage; (4) Other types, such as those for beauty and breast enhancement [4].

2.1. Bioactive components in functional foods and their function

In China, the main sources of ingredients used in functional foods have been categorized into three types: (1) Traditional Chinese medicinal materials, including those that can be used as both food and medicine; (2) Food ingredients, including regular food ingredients, new food ingredients, and food additives; (3) Some natural products and extracts from animals and plants [5]. The special nutritional supplements developed in this project are based on extracts from cruciferous vegetables, including ultrafine powder from specific varieties of cabbage, supplemented with other fruits, vegetables, tea leaves, active polysaccharides, algae, whole grains, medicinal and edible plants, nuts, probiotic powders, β-glucan, or various vitamins, and carrier powders or excipients as needed. The main ingredients in the three products discussed in this paper are cabbage, spinach,

Corresponding authors: * lidan20130505@163.com, **molinfang@126.com,***wjx_de@126.com

acerola cherry (Malpighia emarginata), and yeast β-glucan.

2.1.1 Cabbage

Cabbage, a biennial herbaceous plant in the Brassicaceae family and the Brassica genus, is short and stout, typically spherical, and has high nutritional value. Cruciferous vegetables, including cabbage, Chinese cabbage, rapeseed plants, radish, and mustard, are rich in vitamins, glucosinolates, dietary fiber, important minerals (such as potassium, calcium, and magnesium), and other natural compounds [6]. Studies have shown that cabbage is rich in various vitamins (A, E, C, K1, and U), which help maintain skin health and prevent tumors [7], promote the healing of ulcers. Glucosinolates help boost immunity [9, 10] and have anticancer effects. Dietary fiber promotes intestinal peristalsis, increases nutrient absorption, reduces the absorption of harmful substances (like alcohol, pesticide residues, and food additives), and helps eliminate waste and toxins from the intestines. This reduces the absorption of glucose, fat, and cholesterol in the gastrointestinal tract, which can lower blood fat, aid in weight loss, and regulate blood sugar. In addition, dietary fiber can improve the intestinal environment and alleviate conditions like mouth ulcers and bad breath [11, 12, 13]. Other antioxidants, such as vitamin C, phenolic compounds [14], folic acid, carotenoids, lutein, and anthocyanins, can capture free radicals and help reduce inflammation [15].

2.1.2 Spinach

Studies have shown that spinach has anticancer, weight loss, anti-inflammatory, and blood sugar-lowering effects [16]. It contains chlorophyll, carotenoids, and phenolic compounds, which can improve obesity. It also provides essential amino acids and has high antioxidant capacity. Besides, it is rich in iron, zinc, calcium, ascorbic acid, and protein, making it a potential raw material for dietary supplements [17].

2.1.3 Acerola cherry

Acerola cherries are rich in vitamins A, B, C, and E [18], as well as ascorbic acid and phytonutrients such as carotenoids, phenolic compounds, anthocyanins, and flavonoids [19]. They have properties that help lower blood lipids, reduce blood sugar, and offer antibacterial, antioxidant, and anti-inflammatory effects [20]. In addition, they are high in dietary fiber, which can promote intestinal peristalsis, increase bowel movements, and help prevent constipation.

2.1.4 β-glucan

β-Glucan is the soluble fraction of dietary fiber, a polysaccharide found in cereals, fungi, yeast, algae, and cell walls. Dissolved β-glucan absorbs large amounts of water, forming a highly viscous gum. It is resistant to enzymatic degradation in the stomach, creating a mucus layer that reduces irritation and alleviates inflammation [21]. Studies have shown that yeast-derived β-glucan can reduce cellular permeability and repair the colonic barrier in individuals with gastrointestinal disorders when used as a dietary supplement [22]. It is also beneficial in lowering postprandial blood glucose, insulin levels, and cholesterol; it provides auxiliary effects in cancer treatment [21] and stimulates the immune system, enhancing resistance to various diseases.

2.1.5 Other ingredients

Many other food ingredients also have regulatory effects. For instance, algae can counteract the side effects associated with consuming cruciferous vegetables. Medicinal and edible plants, such as Cassia tora, have functions such as moistening the lungs, promoting bowel movements, nourishing the liver, and protecting the stomach [12]. Natural active polysaccharides enhance immune function, promote disease recovery, exhibit anti-tumor, antioxidant, and anti-inflammatory effects, and reduce blood lipids and blood sugar levels [23]. Vitamin C aids in faster wound healing, improves cholesterol metabolism, prevents cardiovascular diseases, and boosts immunity [24]. Tea polyphenols in tea can stimulate intestinal responses, accelerate intestinal peristalsis, eliminate harmful pathogens causing diarrhea, and improve gut microbiota, thereby enhancing gastrointestinal function [23].

2.2. Processing techniques

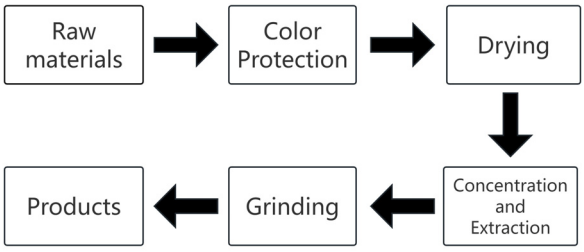

Fig. 1. Production Process of Specialized Composite Fruit and Vegetable Powder

As shown in Figure 1, the composite fruit and vegetable powder developed by the project team involves steps such as color protection, drying, concentration and extraction, grinding, mixing, and shaping.

2.2.1 Color protection

Browning is a common phenomenon in fresh fruits and vegetables during processing or after mechanical damage. It not only affects the appearance, flavor, and nutritional value of the produce but also indicates spoilage or inedibility in certain fruits and vegetables [25]. Methods to prevent browning mainly include blanching, acid solution treatment, sulfur treatment, salt solution, alkaline solution treatment, the addition of color

protectants, edible coatings, and natural plant extracts [25-27]. The application of color protection technology preserves the natural and vibrant colors of cabbage and other fruits and vegetables, enhancing consumer appeal.

2.2.2 Drying

Drying techniques include natural air-drying, high-temperature drying, freeze-drying, far-infrared drying (FIRD), vacuum drying (VD), and freeze-vacuum drying (FD) [28]. These methods reduce moisture content and inactivate enzymes, thereby extending the shelf life of raw materials. However, the active components in food are often unstable and may degrade or volatilize during the drying process. Unstable compounds such as vitamin C are typically used as reference indices for assessing nutritional quality. Selecting the most appropriate drying method helps maximize the retention of active components. Due to the absence of liquid water, an oxygen-free environment (when conducted under vacuum), and low operating temperatures, vacuum freeze-drying preserves the original functionalities of food more effectively than other drying methods. Consequently, it is extensively used for manufacturing high-value food products [29]. Nonetheless, vacuum freeze-drying has drawbacks, including prolonged drying times and high production costs. Emerging technologies, such as infrared-assisted freeze-drying and ultrasonic pretreatment, have been developed to mitigate some of these limitations.

2.2.3 Concentration and extraction

Concentration and extraction techniques include, but are not limited to, solvent extraction, Soxhlet extraction, microwave extraction, ultrasonic extraction, steam distillation, sublimation, pressing, and supercritical carbon dioxide extraction. These methods are employed to enrich and further isolate active components, concentrating the target nutritional elements effectively.

2.2.4 Ultrafine grinding

Ultrafine grinding technology employs specialized grinding equipment to perform processes such as milling, impact, and shearing on fruits and vegetables [30]. This results in powders with particle sizes finer than 100 mesh (≤0.15 nm), maximizing the preservation of the natural color and flavor of the produce while maintaining its nutritional content. The cell wall disruption rate of raw materials exceeds 80%, allowing most plant cell walls to break down and facilitating the rapid release of active components from the plants [11], and improving the utilization of raw materials. This allows for the full enrichment and release of active components, making them more easily released and accessible to the stomach [28], significantly improving the digestibility and absorption efficiency of fruit and vegetable nutrients, increasing the product's nutritional value. Besides, ultrafine grinding effectively processes fibrous, coarse, and hard fruits and vegetables into fine powders with excellent solubility, adsorption, dispersibility, and nutritional activity. These properties make the powders suitable for individuals with weaker digestive functions, facilitating easier consumption and absorption. In addition, nano-sized dietary fibers from fruits and vegetables have a larger surface area, stronger water absorption, increased expansion, and improved water retention capabilities. Compared to conventional food materials, these fibers significantly enhance intestinal peristalsis, promote bowel movements and detoxification, and improve the digestion and absorption of nutrients. This results in fundamental improvements in nutritional functionality while increasing consumer acceptability .

3. Development of functional foods based on cabbage

To address the health issues faced by seafarers and other special populations—such as gastrointestinal disorders, constipation, oral ulcers, hyperlipidemia, obesity, and weakened immunity caused by prolonged lack of fresh fruits and vegetables—the project team developed specialized nutritional supplement products. These products, designed in the form of ordinary food, incorporate functional properties such as alleviating constipation, enhancing immunity, lowering blood lipids, and promoting weight loss, thereby achieving the functionalization of traditional foods. The products are primarily based on cabbage powder and currently hold ten patent applications, including six domestic invention patents and four international PCT invention patents. Among these, two patents have been granted: A Composition for Regulating Human Microbiota and Immune Function (PCT/CN2013/072131) and A Fruit and Vegetable Food for Treating Oral Ulcers and Its Preparation Method (PCT/CN2013/083471). These products use ultrafine cabbage powder derived from specific cabbage varieties and extracts from other cruciferous vegetables as primary ingredients. Additional ingredients, such as other vegetables and fruits, whole grains, medicinal and edible plants, probiotic, β-glucan, or various vitamins, are incorporated based on specific functional needs. Finally, carriers or excipients are added to create convenient forms like fruit and vegetable tablets, noodles, hawthorn cakes, or rice powder. By adjusting the types and ratios of functional components, the products can cater to various functional needs, including improving digestion, relieving constipation, mitigating oral ulcers and bad breath, combating obesity and hyperlipidemia, boosting immunity, and supplementing nutrients. These products are not only flavorful, convenient to consume, and visually appealing but also highly effective, with a shelf life exceeding 12 months.

3.1. Types of the developed functional foods.

3.1.1 Specialized composite fruit and vegetable tablets based on cabbage.

Using wild European cabbage powder as the core ingredient, this product incorporates additional components and is compressed into composite fruit and vegetable tablets (Shown in Figure 2). Wild European cabbage is rich in dietary fiber, which helps alleviate gastrointestinal disorders. It also contains high levels of vitamin B, vitamin K1, vitamin U, and glucosinolates, which promote the rapid healing of ulcers. Furthermore, its glucosinolate content enhances the body's immune mechanisms. Consequently, these tablets may effectively restore and improve symptoms such as oral ulcers, acid reflux, bloating, and constipation.

Fig. 2. Specialized Composite Fruit and Vegetable Tablets

3.1.2 Specialized fruit and vegetable noodles based on cabbage and spinach.

Fig. 3. Specialized Fruit and Vegetable Noodles

Using cabbage powder and spinach powder as the main ingredients, we add wheat flour, drinking water, edible salt, food additives (sodium carbonate), etc., to make fruit and vegetable noodles. The product is rich in vitamin A, which helps maintain night vision and nourishes the skin; it is also rich in glucosinolates, which have antioxidant and anti-aging properties; additionally, it contains vitamins U and K, as well as calcium, iron, and zinc, which work synergistically to provide positive health effects. Therefore, such products have certain nourishing and anti-aging benefits for the skin. The product appearance diagram is shown in Figure 3.

3.1.3 Specialized composite fruit and vegetable cakes based on cabbage, acerola cherry, and yeast β-glucan.

This product is made using cabbage powder, acerola cherry powder, and yeast β-glucan as primary ingredients, adopting the JT-07 food-packaged hawthorn cake format, resembling a hawthorn burger with four outer layers and three inner layers. The final product features an outer layer composed of hawthorn pulp and sucrose, while the inner layers consist of composite fruit and vegetable powder, hawthorn pulp, and malt syrup. The layers are alternately stacked, pressed, and then cut and packaged into the desired dimensions to form the finished product. Cabbage powder, one of the key raw materials, has properties that inhibit oral and gastric ulcers and alleviate constipation. Acerola cherry powder, rich in vitamin C, helps relieve physical fatigue and boosts immunity. Yeast β-glucan also enhances immunity and mitigates fatigue. Therefore, these products offer functional benefits, including the improvement of oral and gastric ulcers, relief from constipation, immunity enhancement, and fatigue reduction. Package and appearance of this product is shown in Figure 4.

Animal experiments indicate that the key ingredient, the specialized composite fruit and vegetable powder, exhibits a certain degree of efficacy in promoting bowel movements, reducing lipids, aiding weight loss, and enhancing immunity, with no toxic side effects. It is inferred that the corresponding finished products retain these functional benefits to some extent.

Fig. 4. Packaging and appearance of Specialized Composite Fruit and Vegetable Cakes

3.2. Related test results of the developed functional foods.

3.2.1 Requirement of food appearance and sensation.

The functional food demonstrated a stable nutritional profile with maintained dimensional stability and chromatic integrity, exhibiting no detectable odor and being devoid of macroscopically observable extraneous particulate matter. Its intact morphological characteristics, combined with enhanced palatability and improved consumer acceptance metrics, collectively validate its physicochemical and organoleptic consistency under standardized evaluation protocols.

3.2.2 Requirements for hygiene.

The functional foods comply with the applicable requirements of national standards such as GB 4810, GB/T 5009. 11, GB/T 5009. 12, GB/T 5009. 15, GB/T

5009. 17, GB/T 5009. 22, GB/T 5009.27, GB/T 4789.2, GB/T 4789.3, GB2760, GB9683 and GJB652B.

3.2.3 Evaluation of safety.

The compound fruit and vegetable pastry are taken as the representative to test its various indexes. According to the inspection report in Table 1, it meets the standards in all items and is safe and edible.

Table 1. Test report on hawthorn burger.

Items	*Standard*	*Results*
Sensory	*Standard 5.2*	*Qualified*
Moisture, %	*≤20*	*13.6*
Total sugar, %	*≤80*	*72.3*
Total bacterial count, CFU/g	*≤1000*	*10*
Coliforms, MPN / 100g	*≤30*	*<30*
Enteropathogenic Bacteria	*Not detected*	*Not detected*
Residual sulfur dioxide, g/kg	*≤0.35*	*Not detected*

3.2.4 Evaluation of taste.

A total of 38 graduate students majoring in food science and engineering who had received sensory evaluation course training and had experience in product sensory evaluation were selected to evaluate the sensory evaluation (acceptability) of the products, and they were given two pieces (20g) per day for 10 days. According to the data in the table 2, 71.05% of the subjects thought that the taste of compound fruit and vegetable pastry was acceptable.

Table 2. Results of sensory index evaluation.

Items	Preference level (number)		
	low	moderate	high
Hardness	2	14	22
Viscosity	11	24	3
Acid-Sugar profile	5	23	10
Graininess	14	18	6
Aftertaste	6	15	17
Total	8 (21.05%)	27 (71.05%)	3 (7.89%)

3.2.5 Evaluation of the function of compound fruit and vegetable powder.

Animal studies have found that: First, it can shorten the first defecation time, and increase the number and weight of feces in mice with constipation. Secondly, it can reduce the content of serum total Cholesterol (TC), triglyceride (TG), Low Density Lipoprotein cholesterol (LDL-C) levels and arteriosclerosis index (AI index) in different degrees. Tissue sections showed that it reduced the fat deposition in the liver of rats, relieved hepatocyte steatosis, and had a inhibitory effect on the expansion and growth of white adipocytes in vivo. It had no damage to the kidney and no toxic side effects. In addition, compound fruit and vegetable powder can reduce the weight gain and fat mass of rats, and significantly reduce the fat/body ratio, suggesting that it had an effect on weight loss. Thirdly, it can obviously enhance the delayed allergic reaction, promote the proliferation and transformation of spleen lymphocytes, and increase the level of serum hemolysin in mice. In conclusion, the compound fruit and vegetable powder demonstrates certain effect in promoting bowel movements, aiding weight loss, lowering blood lipid levels, and enhancing immune function.

4. Current development of functional foods

Thanks to relentless efforts, China's functional food industry has experienced rapid development, culminating in notable progress with steady expansion. The country's unique advantages include its long-standing cultural traditions of "food as medicine," a rich history in traditional Chinese medicine, and dietary therapy theories. China also boasts vast territory with diverse natural conditions, such as varied terrain, soil, and climate, which contribute to abundant and valuable plant resources. Furthermore, the large population base and increasing health awareness drive substantial market demand. In addition, new healthcare reforms prioritizing disease prevention and control provide a promising outlook for functional foods [31, 32]. However, the sector faces numerous challenges, including uneven resource distribution, insufficient product innovation, significant product homogeneity, misalignment between functional ingredients and food resources, unconventional product forms with low public acceptance, and outdated supporting equipment [31-34]. Future development of functional foods should focus on improving product efficacy, functionalizing regular foods, and developing staple functional foods. Emphasis should also be placed on innovation to reduce redundancy, diversify and optimize resource utilization, and enhance product quality. Efforts must target reducing low-level repetitive products and developing novel functional foods with clear dose-effect and structure-function relationships [3]. In addition, the industry should refine segmentation for target populations, address the needs of specific groups, and promote efficient health management. Integrating modern biotechnology and advancing intelligent manufacturing processes are also essential [33].

The specialized nutritional supplements discussed in this article, which use cabbage powder as the main ingredient, are presented in conventional food forms such as tablets, cakes, and noodles, thereby avoiding public resistance to unconventional food forms. By focusing on plant-based raw materials such as fruits, vegetables, and tea, these products capitalize on the advantages of plant resources. Furthermore, they are tailored to address specific health issues that may arise in

particular populations or working environments, achieving target population segmentation. This approach aligns with China's functional food development trends while introducing innovations, aiming to contribute to the growth of the functional food sector.

5. Conclusions

With the rapid development of society, people's lifestyles, eating habits, and dietary structures have undergone significant changes. The incidence of diseases has increased, making health issues particularly important, and at the same time, people are placing greater emphasis on health. Conventional drug treatments are often remedial measures taken after the onset of the disease and may have certain side effects. However, dietary therapies such as functional foods can achieve preventive effects, reduce the occurrence of diseases from the source, and help regulate human health, particularly with issues like subhealth. This paper focuses on a specially formulated nutritional supplement developed by our research team, which uses cabbage powder as its main ingredient, and expands on an analysis of the current status and trends in the development of functional foods. It aims to provide a reference for the development of functional foods, as well as to highlight the promising prospects of developing functional foods with various health benefits. Based on the big data survey of population health status, the development of new special formulated nutritional supplement foods with cabbage and other fruits and vegetables as raw materials can provide relevant reference for the health care service of this conference.

References

1. L. Zhang, *Basic principles and functional ingredients of functional foods*, Food and Machinery, **39(6)**, 247–247 (2023)
2. L. An, and X. Y. Cui, *Research progress on plant-based functional foo*ds, Food Research and Development, **35(15)**, 131–133 (2014)
3. L. L. Fan, H. T. Zhao, K. Q. Zhou, L. Lin, and F. F. Li, *Functional foods and their development trends*, Soil and Crops, **7(4)**, 432–438 (2018)
4. J. X. Zeng, *Research progress on probiotic functional foods*, Food Safety Guide, **26**, 190–192 (2023)
5. B. D. Hui, X. Zhang, and P. Gong, *Application and Research Progress of Food Ingredients in Functional Foods in China*, Food Science, **37(17)**, 296–302 (2016)
6. Y. X. Zou, H. F. Yu, L. Zhang, and R. Zheng, *Dietary vegetable powders modulate immune homeostasis and intestinal microbiota in mice*, Foods, **11(1)**, 27, (2022)
7. J. L. Chen, *High-Yield Cultivation Techniques and Pest Control Methods for Cabbage*, Agricultural Technology and Equipment, **3**, 151–153 (2022)
8. J. L. Kaczmarek, X. Liu, C. S. Charron, J. A. Novotny, E. H. Jeffery, H. E. Seifried, et al, *Broccoli consumption affects the human gastrointestinal microbiota*, Journal of Nutritional Biochemistry, **63**, 27–34 (2019)
9. M. E. W. Morrison, J. M. Joseph, S. E. McCann, L. Tang, H. M. Almohanna, K. B. Moysich, *Cruciferous vegetable consumption and pancreatic cancer: A case-control study*, Cancer Epidemiology, **72(1)**, 52–61 (2021)
10. T. C. Xiao, R. J. Chen, T. Zhou, L. Li, Natural *Compound Powder for Enhancing Immunity and Its Preparation Method and Application*, CN104543811B[P].
11. T. C. Xiao, P. F. Zhang, S. H. Zhou, S. G. Xie, X. H. Wang, *Composition for Improving Obesity and Constipation and Its Preparation Method*, CN105286003A[P]
12. *Frequent Consumption of Cruciferous Vegetables Is Beneficial to Health*, Northern Horticulture, **9**, 56–56 (2012)
13. V. Picchi, R. L. Scalzo, A. Tava, F. Doria, F. Branca, *Phytochemical characterization and in vitro antioxidant properties of four Brassica wild species from Italy*, Molecules, **25(15)**, 3495 (2020)
14. H. A. Alfawaz, K. Wani, H. Alrakayan, A. M. Alnaami, and N. M. Al-Daghri, *Awareness, Knowledge and Attitude towards 'Superfood' Kale and Its Health Benefits among Arab Adults*, Nutrients, **14(2)** (2022)
15. R. Bautista-Pérez, A. Cano-Martínez, E. Gutiérrez-Velázquez, M. Martínez-Rosas, R. M. Pérez-Gutiérrez, F. Jiménez-Gómez, et al, *Spinach methanolic extract attenuates the retinal degeneration in diabetic rats*, Antioxidants, **10(5)**, 717 (2021)
16. M. Opazo-Navarrete, C. Burgos-Díaz, B. Soto-Cerda, T. Barahona, F. Anguita-Barrales, Y. Mosi-Roa, *Assessment of the Nutritional Value of Traditional Vegetables from Southern Chile as Potential Sources of Natural Ingredients*, Plant Foods for Human Nutrition, **76(4)**, 523–532 (2021)
17. M. F. Xu, C. J. Shen, Q. Zhu, Y. S. Xu, C. F. Xue, and B. W. Zhu,et al, *Comparative metabolomic and transcriptomic analyses revealed the differential accumulation of secondary metabolites during the ripening process of acerola cherry (Malpighia emarginata) fruit*, Journal of the Science of Food and Agriculture, **102(4)**, 1488–1497 (2022)
18. A. Prakash, R. Baskaran, *Acerola, an untapped functional superfruit: a review on latest frontiers*, Journal of Food Science and Technology, **55(9)**, 3373–3384 (2018)
19. K. S. Batista, N. L. Soares, V. A. M. Dorand, A. F. Alves, et al, *Acerola fruit by-product alleviates lipid, glucose, and inflammatory changes in the enterohepatic axis of rats fed a high-fat diet*, Food Chemistry, **403**,134322 (2023)

20. S. Gudej, R. Filip, J. Harasym, et al, *Clinical outcomes after oat beta-glucans dietary treatment in gastritis patients*, Nutrients, **13(8)**, 2791 (2021)
21. J. P. Ganda Mall, L. Löfvendahl, C. M. Lindqvist, R. J. Brummer, Å. V. Keita, and I. Schoultz, *Differential effects of dietary fibres on colonic barrier function in elderly individuals with gastrointestinal symptoms*, Scientific Reports, **8(1)**, 13404 (2018)
22. T. C. Xiao, S. G. Xie, Z. Q. Su, and P. F. Zhang. *Composition with Laxative Function and Its Preparation Method*, CN106108018A [P].
23. T. C. Xiao, L. Li, and P. F. Zhang, *Composition for Regulating Gut Microbiota and Immune Function*, CN102813113A [P].
24. H. Wang, A. B. Shen, *Current Status and Development of Fruit and Vegetable Processing Technology*, Agro-Product Processing, **2**, 71–73 (2016)
25. Z. N. Zhang, X. Y. Liu, and Y. Y. Wang, *Research Progress on the Application of Blanching and Color Protection Techniques for Fruits and Vegetables*, Journal of Food Safety and Quality, **9(10)**, 2411–2418 (2018)
26. J. Jin, X. M. Lu, and X. Y. Feng, *Research Progress on Chemical Color Protection Techniques for Fruits and Vegetables*, Journal of Jilin Medical College, **43(1)**, 61–63 (2022)
27. P. Wang, Y. Li, R. Yu, D. Huang, S. Chen, and S. Zhu, *Effects of Different Drying Methods on the Selenium Bioaccessibility and Antioxidant Activity of Cardamine violifolia*, Foods, **12(4)**, 529–551 (2023)
28. S. Bhatta, T. S. Janezic, and C. Ratti, *Freeze-drying of plant-based foods*, Foods, **9(1)**, 87 (2020)
29. X. Zhang, L. Li, and B. Li, *Ultra-Fine Grinding Technology of Functional Foods*, Science and Technology of Food Industry, **31(11)**, 375–378 (2010)
30. C. F. Sun, *Comparison of Functional Food Industries Domestically and Internationally*, Food Science, **30(19)**, 356–359 (2009)
31. N. N. Cheng, *Current Demand and Development Trends of Functional Foods Domestically and Internationally*, Science and Technology of Food Industry, **33(8)**, 428–430 (2012)
32. H. Zhang, W. Y. Wang, Y. Q. Duan, X. F. Ren, H. L. Ma, and J. D. Jia, *Innovation Trends, Key Areas, and Policy Recommendations for Functional Foods in China*, Science and Technology of Food Industry, **36(8)**, 361–364 (2015)
33. Y. Cheng, *Current Status and Trends in the Development of Functional Foods*, Food Safety Guide, **13**, 108–110 (2023)