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Use of Functional Ingredients in Health Food Products

Abstract:
The growing deterioration of environmental conditions, the increasing prevalence of alimentary disorders, and the rising demand for preventive nutrition have intensified scientific and practical interest in functional food products. In contemporary food science, functional ingredients are regarded as physiologically active and safe substances capable of exerting a positive influence on metabolic processes, gastrointestinal physiology, cardiovascular function, immune response, and the overall adaptive potential of the human body. Against this background, particular attention has recently been paid not only to traditional functional components but also to plant-derived micronutrients and phytochemicals that expand the possibilities of health-oriented food design. The aim of this study was to analyse new classes of functional ingredients and their functional properties for further use in health food products. The study was based on an analytical review and systematization of contemporary scientific literature published in 2020–2025, with emphasis on current approaches to the development of functional foods, the integration of bioactive components into food matrices, and the growing relevance of ingredients that may support the organism under prolonged stress and adverse environmental conditions. The methodological framework of the study was guided by the principles of enrichment, replacement, and elimination as key approaches to the formulation of foods with improved health-promoting properties. The results demonstrate that the modern spectrum of functional ingredients has substantially expanded beyond traditionally recognized groups such as dietary fibre, probiotics, and omega-3 fatty acids. Special significance is now attributed to plant-origin functional compounds, including phytosterols, isothiocyanates, indoles, organic polysulfides, lignans, coumarins, tannins, flavonoids, and phenolic acids. These compounds are associated with antioxidant, anti-inflammatory, immunomodulatory, phytoestrogenic, and protective physiological effects and therefore represent a promising basis for the development of special-purpose and health-promoting foods. On this basis, the study identifies a group of practically relevant ingredients for possible inclusion in daily diets and food technologies, namely flaxseed, sesame seeds, sunflower seeds, garlic, horseradish, onions, lupine flour, walnuts, hemp oil, apples, and currants. Their value lies in the combination of biologically active composition, nutritional relevance, and accessibility as food raw materials. It is substantiated that the inclusion of plant-derived functional ingredients in food products can contribute to the diversification of daily diets and to the development of products with enhanced preventive potential. At the same time, the practical implementation of such ingredients requires further technological, nutritional, and product-specific validation. The study concludes that the systematization of plant micronutrients and their food sources broadens the scientific understanding of functional ingredients and provides a conceptual basis for the further development of health food products intended to support the body under conditions of stress, nutritional imbalance, and unfavourable environmental influences.

Keywords: functional ingredients, functional foods, health food products, plant-derived bioactive compounds, phytochemicals, preventive nutrition, food enrichment, health-promoting nutrition, dietary sources, food product development.

Introduction

At the present stage of food science and technology development, increasing attention is being paid to products that not only satisfy basic physiological needs for energy and nutrients but also contribute to the maintenance of health, adaptation, and disease prevention. This shift is associated with the growing deterioration of environmental conditions, the increasing prevalence of nutrition-related disorders, chronic stress, metabolic imbalance, and the need to improve the quality of daily diets through scientifically substantiated food solutions (*Gacche & Gacche, 2021*; *Jedrusek-Golińska et al., 2020*; *Stetsenko et al., 2023*; *Stetsenko, 2024*). In this context, functional foods have become one of the most dynamically developing areas of modern nutrition science, as they are designed to provide benefits beyond basic nutritional value and to support specific physiological functions of the human body (*Alongi & Anese, 2021*; *Topolska et al., 2021*).

A functional ingredient is generally understood as a physiologically active and safe substance, or a complex of substances, of plant, animal, microbiological, or mineral origin that is intentionally incorporated into food products in order to produce a beneficial effect on the body (*Alongi & Anese, 2021*; *Topolska et al., 2021*). Such ingredients may influence metabolic regulation, gastrointestinal physiology, cardiovascular function, the condition of intestinal microflora, immune responsiveness, and the organism's resistance to adverse endogenous and exogenous factors (*Jedrusek-Golińska et al., 2020*; *Topolska et al., 2021*). Accordingly, the concept of health-promoting nutrition has evolved from simple nutrient replacement toward the creation of food products with targeted biological properties and a preventive orientation. In this paradigm, food is increasingly regarded not only as a source of nourishment but also as an important instrument for maintaining functional homeostasis and reducing the risk of nutrition-related disorders.

The development of functional foods has a substantial scientific, social, and technological basis. The concept itself, which gained international recognition after its institutionalization in Japan, has stimulated the formation of a broad research field focused on bioactive food components, enriched products, personalized nutrition, and the design of foods with improved physiological properties (*Alongi & Anese, 2021*; *Woollen, 1990*). Contemporary scientific literature demonstrates a rapid transition from traditional functional ingredients such as dietary fibre, vitamins, probiotics, minerals, and polyunsaturated fatty acids to more complex systems of biologically active compounds, including phytochemicals of plant origin (*Alongi & Anese, 2021*; *Capanoglu et al., 2024*; *Gacche & Gacche, 2021*; *Jedrusek-Golińska et al., 2020*; *Topolska et al., 2021*). Current research particularly emphasizes the need to combine high nutritional value, technological feasibility, bioavailability, and physiological relevance when introducing such compounds into food matrices (*Alongi & Anese, 2021*; *Capanoglu et al., 2024*; *Jedrusek-Golińska et al., 2020*).

In recent years, the scientific discourse on functional foods has increasingly focused on the role of plant-derived bioactive compounds as promising components of health-oriented food systems. These include phytosterols, flavonoids, phenolic acids, lignans, isothiocyanates, indoles, tannins, coumarins, and other classes of compounds naturally present in vegetables, fruits, berries, legumes, nuts, seeds, and plant oils. Their growing relevance is explained by a broad

spectrum of reported physiological effects, including antioxidant, anti-inflammatory, immunomodulatory, cardioprotective, phytoestrogenic, and adaptive properties (*Alongi & Anese, 2021*; *Capanoglu et al., 2024*; *Gacche & Gacche, 2021*; *Jedrusek-Golińska et al., 2020*; *Topolska et al., 2021*). Such compounds significantly expand the conventional classification of functional ingredients and open new prospects for the design of foods intended for daily consumption, preventive nutrition, and special-purpose dietary support.

At the same time, despite the considerable volume of publications devoted to functional nutrition, a number of important issues remain insufficiently systematized. First, the scientific literature often addresses particular bioactive compounds or individual product categories, whereas the selection of plant-derived functional ingredients as a coherent group for health food development is discussed less systematically. Second, although numerous studies describe the biological activity of phytochemicals, fewer works present them in a form directly relevant to food product design, that is, by linking the class of functional compounds, their natural dietary sources, and their practical applicability in health-promoting foods (*Alongi & Anese, 2021*; *Bomba et al., 2023*; *Capanoglu et al., 2024*; *Simakhina et al., 2024*). Third, in the context of current nutritional challenges, including prolonged stress and unfavourable environmental influences, there is a need for a clearer conceptual basis for selecting ingredients that are both biologically valuable and technologically relevant for incorporation into products of everyday diets (*Simakhina et al., 2024*; *Stetsenko et al., 2023*; *Stetsenko, 2024*).

The subject of the study is the functional properties, natural dietary sources, and practical relevance of selected plant-based bioactive compounds for their possible use in the development of health-promoting food products. The object of the study is health food products enriched with plant-derived functional ingredients. In this perspective, the study focuses not only on the biological significance of such ingredients, but also on their applicability in the diversification and nutritional improvement of foods intended for daily consumption.

This study proceeds from the assumption that the expansion of the functional ingredient spectrum through the systematization of plant-derived micronutrients and phytochemicals can strengthen the scientific basis for the development of health food products. In this regard, the object of the study is health food products enriched with plant-derived functional ingredients, while the subject of the study is the functional properties, dietary sources, and practical relevance of selected plant-based bioactive components for use in such products.

The aim of the study is to analyse new classes of functional ingredients and their functional properties for further use in health food products.

To achieve this aim, the following tasks were set: (1) to characterize the current range of functional ingredients in modern nutrition science; (2) to identify the principal classes of plant-derived functional compounds relevant to health-promoting foods; (3) to determine their major natural food sources; and (4) to substantiate the selection of ingredients that may be used in the development and diversification of foods intended for daily diets.

The scientific novelty of the study lies in the applied systematization of plant-derived functional ingredients not merely as isolated biologically active substances, but as a meaningful group of food-relevant components that can be used as a basis for expanding the range of health food products. In contrast to purely descriptive classifications of functional ingredients, this study focuses on those plant-origin compounds that combine physiological significance, natural

occurrence in commonly available raw materials, and practical prospects for incorporation into food technologies. Particular attention is paid to ingredients that may be relevant in conditions where the body requires additional nutritional support, including prolonged stress, nutritional imbalance, and unfavourable environmental exposure (*Simakhina et al., 2024*; *Stetsenko et al., 2023*; *Stetsenko, 2024*).

The practical significance of the study is determined by the possibility of using the obtained systematization in the design of new food products with health-promoting properties, in the enrichment of daily diets, and in the substantiation of ingredient selection for restaurant, food-service, and food-manufacturing applications. The identification of promising plant-derived ingredients and the clarification of their functional roles can contribute to the development of nutritionally improved foods that are more responsive to current public health needs. Thus, the study is positioned at the intersection of food technology, functional nutrition, and preventive dietetics and provides a conceptual basis for the further development of health-oriented food products.

The results of this study are intended for a broad interdisciplinary audience involved in the development, evaluation, and practical application of health-oriented food systems. They may be of particular relevance to researchers in food science, nutrition, and preventive dietetics; technologists engaged in the formulation of functional and special-purpose food products; specialists in restaurant and food-service innovation; and professionals concerned with improving dietary quality under conditions of stress, nutritional imbalance, and adverse environmental influences. In addition, the systematized findings may be useful for educators, postgraduate students, and graduate students working in the fields of food technology, public health nutrition, and the scientific substantiation of enriched and health-promoting diets.

Materials and Methods

This study was designed as an analytical review with elements of applied systematization aimed at identifying and substantiating plant-derived functional ingredients that may be relevant for the development of health food products. The research did not involve experimental laboratory modelling, sensory assessment, or clinical verification. Instead, it focused on the conceptual and analytical generalization of current scientific approaches to functional nutrition, the classification of bioactive compounds of plant origin, and the identification of food-relevant ingredients with potential health-promoting significance.

The choice of this design was determined by the purpose of the study, namely to analyse new classes of functional ingredients and their functional properties for further use in health food products. Accordingly, the study was oriented toward the structured interpretation of scientific data, the comparative consideration of plant-derived compounds in terms of their biological roles, and the selection of ingredients that may be incorporated into foods intended for daily diets and preventive nutrition.

The source base of the study consisted of contemporary scientific publications devoted to functional foods, functional ingredients, plant-derived bioactive compounds, and health-promoting nutrition. Particular attention was paid to publications issued in 2020–2025, since this period reflects the most recent stage in the development of scientific thought on enriched foods,

bioactive food systems, and the role of plant micronutrients in the nutritional support of the human body under adverse environmental and physiological conditions.

The analytical materials included review studies, scientific articles, and selected Ukrainian and international publications addressing the concept of functional foods, the integration of bioactive components into food matrices, the technological development of health-oriented products, and the physiological relevance of plant-based micronutrients. In addition, the study considered sources focused on the practical use of plant raw materials and functional ingredients in special-purpose and health-promoting foods. The analysed publications were selected for their thematic relevance to the subject of the study and their ability to support the systematization of ingredients applicable to food product design.

The selection of plant-derived functional ingredients was carried out according to a set of conceptual and applied criteria. First, the ingredient had to be of plant origin and contain bioactive compounds that are recognized in the scientific literature as potentially relevant to the maintenance of health and the support of physiological functions. Second, the selected ingredient had to represent a meaningful source of one or more functional classes of compounds, such as phytosterols, flavonoids, phenolic acids, lignans, isothiocyanates, indoles, tannins, or related micronutrients.

Third, preference was given to ingredients that are naturally present in raw materials suitable for human consumption and compatible with the structure of daily diets. Fourth, the ingredient had to demonstrate practical potential for incorporation into food products, including dishes and formulations intended for health-promoting nutrition. Fifth, the selected set of ingredients was expected to reflect the diversity of plant-derived functional compounds rather than a single narrow phytochemical category. On this basis, the study concentrated on such ingredients as flaxseed, sesame seeds, sunflower seeds, garlic, horseradish, onions, lupine flour, walnuts, hemp oil, apples, and currants as representative raw materials combining biological relevance and practical food applicability.

The analytical procedure was implemented in several successive stages. At the first stage, the study summarized contemporary scientific approaches to the understanding of functional foods and functional ingredients, including the transition from traditional enrichment models toward foods with enhanced physiological and preventive properties. At the second stage, the main classes of plant-derived functional compounds described in the literature were identified and grouped according to their biological and nutritional significance.

At the third stage, natural food sources of these compounds were analysed in order to determine ingredients that may be realistically used in the development of health food products. This stage involved the systematization of vegetables, fruits, berries, seeds, nuts, plant oils, and other raw materials as carriers of bioactive compounds relevant to the subject of the study. At the fourth stage, the selected ingredients were generalized from the perspective of their possible contribution to the diversification and nutritional improvement of daily diets. Their significance was interpreted through the combination of three interrelated dimensions: the presence of bioactive compounds, the expected health-promoting potential, and the practical suitability of the ingredient for use in food technologies.

In methodological terms, the study also took into account the classical approaches commonly used in the development of functional foods, namely enrichment, replacement, and

elimination. However, in this study these approaches were not treated as independent experimental procedures, but rather as a conceptual technological framework that explains how selected functional ingredients may subsequently be introduced into product formulations. Thus, the principal method of the present research was analytical systematization, whereas the technological approaches served as an interpretative basis for the further practical application of the identified ingredients.

The study has several limitations that should be taken into account when interpreting its results. First, it has an analytical and conceptual character and does not include experimental validation of the selected ingredients in specific food systems. Second, the study does not assess dosage parameters, bioavailability in particular matrices, organoleptic compatibility, or stability during technological processing and storage. Third, the conclusions regarding the health-promoting significance of the selected ingredients are based on the generalization of scientific literature and should therefore be understood as a conceptual basis for further applied and experimental research rather than as final evidence of product efficacy.

Despite these limitations, the chosen methodological approach made it possible to identify and systematize a relevant group of plant-derived functional ingredients, clarify their principal food sources, and substantiate their potential relevance for the further development of health food products.

Literature Review

The scholarly understanding of functional foods has evolved from a market-oriented and category-defining concept into a multidisciplinary field that integrates food science, nutrition, preventive medicine, consumer research, and product development. One of the earlier signals of this transition was the recognition of functional foods as a distinct and emerging market segment, where value was created not only through conventional nutritional composition but also through added physiological relevance (*Woollen, 1990*). In contemporary research, however, the concept has moved considerably beyond the notion of a "new market" and is now treated as a scientific and technological platform for designing foods capable of supporting specific bodily functions and improving health outcomes. This shift has made functional ingredients central to the development of foods that combine nutritional adequacy with preventive and adaptive potential.

A major line of recent international research is connected with the expansion of the conceptual boundaries of functional food itself. Topolska et al. (*2021*) demonstrate that consumer interest in functional foods is shaped not only by health concerns in a general sense, but also by expectations of concrete physiological benefits, trust in product composition, and the perceived legitimacy of food as a vehicle of health support. This consumer-centred perspective is important because it shows that functional foods are not interpreted solely through laboratory or technological parameters; they also exist within a framework of public expectations regarding quality of life, disease prevention, and informed dietary choice. Complementing this view, Capanoglu et al. (*2024*) frame functional foods as a field in which added value is generated through the purposeful enrichment of foods with biologically meaningful compounds, thereby linking scientific innovation with nutritional relevance and product differentiation.

At the same time, the literature increasingly suggests that the development of functional foods cannot be reduced to the mechanical addition of isolated compounds to conventional products. Alongi and Anese (*2021*) argue for a holistic approach to functional food development, emphasizing that the success of such products depends on the interaction between ingredient functionality, food matrix compatibility, processing effects, bioavailability, and the intended physiological outcome. This position is especially important for current food technology, because it shifts the focus from a narrow enrichment logic to a systems-oriented model in which functional ingredients must be evaluated not only for their biological activity, but also for their technological feasibility and nutritional performance in real food systems. In this sense, the contemporary literature increasingly supports the idea that the scientific validity of a functional ingredient must be matched by its practical applicability in product formulation.

Another major tendency in the literature is the differentiation of functional foods according to target groups and specific physiological or life-condition needs. Jedrusek-Golińska et al. (*2020*), e.g., demonstrate in their narrative review that functional foods for older adults should be considered within a highly specific nutritional framework that accounts for age-related physiological changes, health vulnerabilities, and the need for products with both nutritional density and functional efficacy. In a different but equally important direction, Gacche and Gacche (*2021*) examine the role of functional foods, nutraceuticals, and dietary supplements in cancer prevention, thereby extending the discussion toward food-mediated protective strategies in relation to one of the most serious contemporary health challenges. Together, these studies show that the field of functional nutrition is increasingly moving toward more differentiated, condition-sensitive, and population-oriented models, rather than relying on a universal or purely generalized understanding of beneficial food products.

Within the Ukrainian scientific context, the literature develops this logic further by linking functional ingredients with the nutritional needs of specific social groups and with the realities of adverse living conditions. Simakhina et al. (*2024*) address the conceptual foundations of combined food ration formation for extreme living conditions, thereby emphasizing that food design under such circumstances requires more than conventional nutrient balancing; it requires a strategic combination of ingredients capable of supporting adaptation, resilience, and physiological stability. A related applied direction is represented by Masliichuk and Kravets (*2024*), who consider functional ingredients as components of new food products for military personnel. Their contribution is important because it translates the broader functional-food discourse into the domain of specialized nutrition, where the requirements of bodily support, practicality, and nutritional efficiency are especially stringent. These studies indicate that, in the Ukrainian scholarly environment, functional nutrition is increasingly interpreted not only as a preventive public-health tool, but also as a strategic response to extreme, stress-related, and service-related conditions of life.

A similar problem orientation is found in recent Ukrainian works devoted to wartime nutrition and stress-related dietary support. Stetsenko et al. (*2023*) emphasize the importance of functional nutrition for maintaining the health of the population of Ukraine under wartime conditions, thereby underscoring the role of food products enriched with biologically active components in situations where ordinary dietary patterns are disrupted and the physiological burden on the body increases. Stetsenko (*2024*) further develops this line by focusing specifically

on functional food products and ingredients aimed at overcoming the effects of stress among the population under martial law. Taken together, these studies strengthen the idea that functional ingredients should be evaluated not only from the standpoint of generic health improvement, but also in relation to their capacity to support the organism in circumstances of prolonged psycho-emotional strain, unstable living conditions, and increased exposure to harmful environmental factors. For the present study, this body of literature is especially significant because it helps justify the relevance of plant-derived ingredients as components of foods intended for supportive and adaptive nutrition.

Another important segment of the literature concerns the role of non-traditional and regionally specific plant raw materials in developing health-promoting foods and beverages. Bomba et al. (*2022*) examine the use of non-traditional raw materials in preparing health-promoting children's meals in restaurant establishments, thereby highlighting the technological and nutritional relevance of expanding the ingredient base beyond standard formulations. This contribution is methodologically important because it connects functional nutrition with the restaurant and food-service sector, where enriched and health-oriented dishes can be adapted for real consumer practice. In a related study, Bomba et al. (*2023*) analyse non-traditional plant raw materials of the Carpathians in the technology of preparing health-promoting beverages. This regional focus is valuable because it demonstrates that functional food development may rely not only on globally standardized ingredients, but also on local plant resources with significant health-promoting potential. Together, these studies support the view that non-traditional plant raw materials can serve as a meaningful basis for the diversification of functional foods and beverages, especially when local biodiversity and regional technological traditions are taken into account.

Across both international and Ukrainian sources, one of the most stable research tendencies is the growing importance of plant-derived bioactive compounds as functional ingredients. Although the cited sources vary in scale and focus—from broad conceptual discussions to population-specific and application-oriented studies—they collectively point to the increasing role of ingredients rich in phytochemicals, antioxidants, and other biologically active compounds in the design of modern health-oriented foods (*Alongi & Anese, 2021*; *Capanoglu et al., 2024*; *Simakhina et al., 2023*; *Stetsenko, 2024*). This convergence is particularly important for the present study because it supports the analytical shift from a narrow emphasis on conventional functional ingredients, such as fibre or probiotics alone, toward a broader classification that includes plant micronutrients and phytochemical complexes occurring naturally in seeds, nuts, fruits, berries, vegetables, and plant oils. In other words, the literature increasingly allows functional ingredients to be interpreted not only as isolated additives, but also as compounds embedded in natural food raw materials with potential technological and nutritional relevance.

Nevertheless, despite the breadth of existing studies, the reviewed literature also reveals a number of unresolved issues. First, many publications focus either on the general concept of functional foods or on specific target populations, without providing a sufficiently systematized selection of plant-derived ingredients that could serve as a practical basis for product development. Second, the connection between biological activity and food-technological applicability is not always made explicit: a compound may be recognized as promising in nutritional or biomedical terms, yet its relevance for actual food matrices, everyday diets, or

specific product categories may remain insufficiently articulated. Third, while Ukrainian studies make an important contribution by addressing health-promoting foods in the contexts of restaurant practice, regional plant resources, military nutrition, wartime conditions, and stress adaptation (*Bomba et al., 2022*; *Bomba et al., 2023*; *Masliichuk & Kravets, 2024*; *Stetsenko et al., 2023*; *Stetsenko, 2024*), this body of work still requires stronger analytical systematization around classes of plant-derived functional compounds and their major dietary sources.

Therefore, the current state of research makes it possible to identify a clear scholarly rationale for the present study. On the one hand, the literature convincingly demonstrates that functional foods are now understood as an important means of supporting health, preventing nutrition-related disorders, and responding to the needs of specific population groups and adverse living conditions (*Gacche & Gacche, 2021*; *Jedrusek-Golińska et al., 2020*; *Stetsenko et al., 2023*). On the other hand, there remains a need for a more integrated and application-oriented systematization of plant-derived functional ingredients that would connect their biological significance, natural dietary sources, and potential use in health food products (*Alongi & Anese, 2021*; *Bomba et al., 2023*; *Capanoglu et al., 2024*; *Simakhina et al., 2024*). It is precisely this gap that defines the relevance of the present research, which aims to analyse new classes of functional ingredients and substantiate their value for the further development of health-promoting foods.

Results

Expansion of the Functional Ingredient Spectrum in Modern Nutrition

Japanese researchers initially identified lactic acid bacteria and bifidobacteria, oligosaccharides, dietary fiber, and omega-3 fatty acids as the principal categories of physiologically functional ingredients used in the production of functional foods (*Woollen, 1990*). At present, however, this list has expanded significantly. Functional products and dietary supplements now include previously less studied functional ingredients of plant origin, namely phytochemicals, which have no energy or plastic value and are not essential nutrients in the classical sense, yet play an important role in maintaining human health.

This expansion of the functional ingredient spectrum reflects a broader understanding of health-promoting nutrition. Modern scientific research confirms that plant-based micronutrients and phytochemicals significantly broaden the classification of functional ingredients in foods intended for daily consumption and in special-purpose products. Various plant raw materials act as natural carriers of these compounds, including vegetables, fruits, berries, cereals, legumes, nuts, seeds, and plant oils. In this context, the inclusion of plant-origin bioactive components in the diet represents an important direction in the diversification and nutritional improvement of food products.

Major Classes of Plant-Derived Functional Compounds

The plant-derived functional ingredients identified in the study include several important groups of biologically active compounds. These comprise phytosterols from beans, vegetables, fruits, sunflower seeds, and nuts; isothiocyanates and indoles from cruciferous vegetables; organic polysulfides from garlic and onions; lignans (aglycone phytoestrogens) from flax seeds, sesame seeds, bran, and soybeans; coumarins from celery, parsley, and parsnips; plant quinones

(tannins) from walnuts, leafy vegetables, spinach, and soybeans; flavonoids from fruits and vegetables, tea, and wine; and phenolic acids from fruits and vegetables, berries, tea, wine, cocoa, and chocolate.

A substantial part of these compounds is associated with antioxidant and protective activity. Flavonoids, phytosterols, tannins, phenolic acids, lignans, saponins, terpenoids, and carotenoids are regarded as antioxidants that may reduce the risk and slow the development of degenerative processes in the body. Their significance is linked to their ability to participate in maintaining metabolic balance, protecting tissues from oxidative damage, and supporting adaptive physiological mechanisms.

Special attention should be paid to cruciferous vegetables as sources of glucosinolates and related compounds. Brussels sprouts, broccoli, other types of cabbage, rutabaga, turnips, horseradish, and watercress may serve as valuable dietary sources of indoles and isothiocyanates. These compounds help normalize endocrine system function, maintain hormonal balance, and strengthen immune defense. In the context of specialized and supportive nutrition, such properties make cruciferous raw materials promising components of health-oriented food products.

Selected Ingredients for Health Food Products

In order to expand the range of functional foods in daily diets, a group of practically significant ingredients was selected in this study (*Table 1*). These ingredients are flaxseed, sesame seeds, sunflower seeds, garlic, horseradish, onions, lupine flour, walnuts, hemp oil, apples, and currants. Their selection was based on their functional properties, their natural occurrence as food raw materials, and their potential suitability for incorporation into health-promoting products.

The selected ingredients represent different groups of plant-derived functional compounds and therefore provide a broad basis for the enrichment and diversification of foods. Flaxseed and sesame seeds are important sources of lignans; sunflower seeds contribute phytosterols and isoflavone-related compounds; garlic and onions are valuable due to their sulfur-containing phytochemicals; walnuts provide tannins and other antioxidant compounds; apples and currants are important sources of flavonoids and phenolic acids; and hemp oil serves as a plant-derived lipid component of high nutritional relevance. Lupine flour is of particular interest as a technologically convenient ingredient that may expand the protein and functional composition of food systems.

Given their functional properties, the incorporation of these ingredients into foods may contribute to the production of higher-quality products with health-promoting characteristics. Their use appears especially promising for the development of foods intended for daily diets, product diversification, and the support of the organism under conditions requiring improved nutritional quality.

Functional Characteristics of Selected Compound Groups

Among the selected groups of compounds, phytoestrogens and lignans deserve particular attention. Isoflavones are described as compounds that inhibit the formation of blood clots in blood vessels, thereby helping to prevent the blockage of coronary arteries and reducing the risk

of myocardial infarction. The consumption of phytoestrogens is also associated with a lower risk of colon, breast, prostate, stomach, and lung cancer. In this regard, ingredients containing such compounds may be considered especially relevant for foods with preventive nutritional orientation.

Lignans are characterized by a wide spectrum of functional properties, including antiviral, antibacterial, antifungal, antioxidant, phytoestrogenic, and oncoprotective effects. Their presence in flax seeds, sesame seeds, and several other plant raw materials further supports the selection of these ingredients for use in health food products. From the standpoint of functional nutrition, lignan-containing ingredients are valuable because they combine biological activity with accessibility in ordinary diets.

Flavonoids also occupy a central place among plant-derived functional compounds. Under the influence of enzymes, flavonoids are broken down into sugars and aglycones. Representatives of flavanols include catechins and proanthocyanidins. Catechins are antioxidants that inhibit the development of cancerous tumors and the activation of carcinogens. Pycnogenol exhibits anticoagulant properties comparable to those of aspirin and therefore may reduce the risk of myocardial infarction and stroke. Proanthocyanidins strengthen and restore connective tissue, including in the cardiovascular system, and reduce allergic inflammatory manifestations by decreasing histamine production.

In addition, flavonoids demonstrate anti-allergic and anti-inflammatory effects through the inhibition of the formation and release of inflammatory factors, as well as considerable antiviral activity, slowing the reproduction and activity of viruses. Quercetin is described as having particularly high antiviral activity against herpes, parainfluenza, and other viruses. Many flavonoids, especially catechins and anthocyanins, also possess P-vitamin activity. They normalize and strengthen capillary condition, enhance the effect of ascorbic acid by protecting it from oxidation, and help normalize blood pressure due to their antispasmodic effect on the smooth muscles of blood vessels.

Main Dietary Sources of the Identified Compounds

The identified classes of plant-derived functional compounds are linked to specific dietary sources, which makes their inclusion in food systems technologically and nutritionally feasible. As shown in Table 1 (*Appendix*), phytosterols are associated with unrefined vegetable oils, soybeans, oats, amaranth, vegetables, and fruits; sulfur-containing phytochemicals are present in cruciferous vegetables, garlic, and onions; isoflavones occur in soybeans and other legumes, sunflower seeds, dates, cabbage, and hops; lignans are found in flax seeds, sesame seeds, bran, rye, nuts, cherries, apples, parsley, carrots, and garlic; saponins are associated with green vegetables, potatoes, and edible green shoots; flavonoids are abundant in berries, fruits, vegetables, citrus fruits, tea, wine, and soy; and phenolic acids are present in apples, blueberries, cherries, plums, potatoes, nuts, soy, and coffee beans.

Thus, the results obtained in the study confirm the importance of plant-based micronutrients in the daily diet and substantiate the relevance of their use in the development of health food products. Since many of these compounds are naturally distributed across commonly available plant foods, their inclusion in daily diets may be considered a realistic and promising strategy for improving nutritional quality. In this regard, the recommended minimum daily intake

of vegetables and fruits at the level of 500–600 g acquires additional significance, since such products serve not only as nutrient sources in the conventional sense but also as carriers of important functional compounds.

Discussion

Scientific Interpretation of the Identified Plant-Derived Functional Ingredients

The results of the present study confirm that the contemporary understanding of functional ingredients has moved far beyond the classical categories that were initially associated with functional foods, such as dietary fibre, probiotics, and omega-3 fatty acids. In current food science, increasing importance is attached to plant-derived bioactive compounds that, although not essential nutrients in the strict classical sense, may significantly contribute to the physiological support of the body and to the preventive orientation of daily nutrition. In this respect, the identified groups of substances—phytosterols, isothiocyanates, indoles, sulfur-containing phytochemicals, lignans, flavonoids, phenolic acids, and related compounds—should be interpreted not merely as isolated biochemical components, but as a meaningful functional basis for the development of health-promoting food systems (*Alongi & Anese, 2021*; *Capanoglu et al., 2024*).

This interpretation is consistent with the broader shift in the scientific literature toward a more integrated understanding of food functionality. Functional foods are increasingly perceived not only as enriched products but also as carriers of adaptive, protective, and physiologically relevant compounds that may contribute to the maintenance of homeostasis under adverse dietary and environmental conditions (*Jedrusek-Golińska et al., 2020*; *Topolska et al., 2021*). Against this background, the present results are important because they substantiate the relevance of naturally occurring plant ingredients as practical sources of such compounds, thereby connecting the biochemical dimension of food functionality with the raw-material and product-development dimension of food science.

A particularly important finding of the study is that plant-derived ingredients can be grouped not only according to their botanical origin, but also according to their expected functional roles in the diet. Seeds, nuts, fruits, berries, oils, cruciferous vegetables, and leguminous raw materials provide different but complementary classes of bioactive compounds. This means that the functional potential of a product is determined not by a single universal ingredient, but by the possibility of combining various plant sources that differ in phytochemical profile, nutritional density, and technological use. Such an interpretation strengthens the argument that the practical development of health food products should rely on a diversified ingredient strategy rather than on a narrowly additive approach (*Alongi & Anese, 2021*; *Simakhina et al., 2024*).

Relevance of the Selected Ingredients for Health Food Product Development

The selected ingredients identified in the study—flaxseed, sesame seeds, sunflower seeds, garlic, horseradish, onions, lupine flour, walnuts, hemp oil, apples, and currants—should be viewed as a functionally heterogeneous yet technologically meaningful group. Their relevance lies in the fact that they combine three important characteristics: first, they are natural dietary sources of biologically active compounds; second, they are potentially compatible with a wide

range of food matrices; and third, they are sufficiently accessible to be considered realistic components of foods intended for everyday consumption. This combination of biological significance and practical applicability is especially important for developing health-promoting foods, because a theoretically valuable ingredient has limited importance if it cannot be reasonably incorporated into food products or daily diets.

From this standpoint, the identified ingredients may be interpreted as particularly promising for the design of foods with preventive and supportive nutritional properties. Flaxseed and sesame seeds are of special value because they are associated with lignans and related phytoestrogenic compounds, which broadens their relevance for foods intended to support metabolic and hormonal balance. Garlic, onions, and horseradish are important due to sulfur-containing phytochemicals and compounds characteristic of cruciferous or related plant systems, which are associated in the literature with protective and adaptive physiological effects. Apples and currants are significant as familiar and accessible carriers of flavonoids and phenolic acids, while walnuts and hemp oil contribute to the enrichment of food systems through antioxidant and lipid-related nutritional value. Lupine flour deserves separate attention because, unlike some ingredients that function mainly as bioactive carriers, it also has clear technological relevance as a structurally useful and nutritionally meaningful component in product formulations.

In this context, the results of the study support the idea that the development of functional foods should not be limited to the use of highly specialized or costly ingredients. On the contrary, one of the strengths of the selected set is that it includes raw materials that are relatively familiar, available, and acceptable within ordinary food culture. This characteristic increases the practical significance of the study, because it makes the proposed ingredients relevant not only for theoretical classification but also for actual application in food-service practice, restaurant technologies, and the development of health-oriented foods for wider population groups (*Bomba et al., 2022*; *Bomba et al., 2023*).

Functional Ingredients as a Bridge between Preventive Nutrition and Specialized Dietary Support

The discussion of the present findings also needs to be placed within the broader framework of target-oriented and condition-sensitive nutrition. Contemporary literature increasingly demonstrates that functional food systems are especially relevant when nutrition must serve not only a general health-maintenance role, but also a supportive role under specific physiological or social conditions. This is evident in studies addressing older adults, chronic-disease prevention, military nutrition, and wartime or stress-related dietary challenges (*Gacche & Gacche, 2021*; *Jedrusek-Golińska et al., 2020*; *Masliichuk & Kravets, 2024*; *Stetsenko et al., 2023*).

Within this perspective, the selected ingredients in the present study may be regarded as especially relevant for nutritional contexts in which the body is exposed to prolonged stress, unstable living conditions, or increased adaptive burden. Ukrainian researchers have already emphasized the importance of functional nutrition for the support of the population under wartime conditions and for the development of special-purpose products aimed at maintaining resilience and health under adverse circumstances (*Stetsenko et al., 2023*; *Stetsenko, 2024*). Similarly, Simakhina et al. (*2024*) underline the need for conceptually substantiated food rations for extreme living conditions, where the combination of nutritional adequacy and biologically active

support becomes critically important. The results of the present study do not claim to provide direct experimental evidence for stress mitigation; however, they do support the idea that plant-derived functional ingredients may form a meaningful nutritional basis for foods intended to strengthen the preventive and adaptive properties of daily diets.

This interpretation is further reinforced by the applied relevance of selected ingredients to foods designed for specific groups. Masliichuk and Kravets (*2024*) argue that the inclusion of functional ingredients in products for military personnel should be regarded as a strategically important direction in the development of new food products. In a broader sense, this implies that the scientific value of plant-derived bioactive components lies not only in their abstract physiological potential, but also in their ability to serve as components of food systems intended for populations facing increased physiological and psycho-emotional stress. Thus, the present study contributes to the ongoing scholarly discussion by systematizing ingredients that may be relevant both for preventive nutrition and for more specialized health-supportive dietary contexts.

Technological and Food-System Implications

An important contribution of the present results lies in their technological interpretability. Modern food science increasingly emphasizes that functional food development must consider not only the presence of bioactive compounds, but also the way these compounds can be incorporated into actual food systems (*Alongi & Anese, 2021*). In this regard, the ingredients identified in the study possess different technological profiles that may be used in the formulation of a broad range of products. Seeds and seed-derived components may be incorporated into bakery items, porridges, bars, salads, fermented products, and dry mixes. Hemp oil and walnut-derived components may enrich sauces, dressings, spreads, and cold dishes. Apples and currants may be used in beverages, desserts, fillings, snacks, fruit-based sauces, and functional semi-finished products. Garlic, onions, and horseradish may be integrated into savory dishes, sauces, marinades, meat analogues, vegetable systems, and complex multi-component formulations. Lupine flour has additional importance for its structuring, protein-enriching, and textural role in flour-based and hybrid food systems.

This technological diversity is especially important because it allows plant-derived functional ingredients to be considered within the logic of product architecture rather than as abstract nutritional additives. The present study therefore supports the idea that functional ingredients can be introduced through several pathways: enrichment of conventional food products, replacement of nutritionally weaker components with more valuable analogues, and the design of new dishes or products in which selected ingredients are integral rather than auxiliary elements. This interpretation also resonates with Ukrainian applied studies on the use of non-traditional plant raw materials in restaurant practice and health-promoting beverages, where raw-material innovation is directly linked to the diversification of food offerings and to the practical realization of health-oriented nutritional concepts (*Bomba et al., 2022*; *Bomba et al., 2023*).

At the same time, the study suggests that technological promise should not be equated automatically with proven efficacy. A functionally promising ingredient may remain underutilized if its sensory characteristics, dosage thresholds, compatibility with other ingredients, or stability during processing are not sufficiently studied. Therefore, the practical

value of the present results lies less in the claim that all selected ingredients are equally ready for immediate industrial deployment, and more in the creation of a scientifically grounded shortlist of ingredients whose further technological elaboration appears justified.

Comparison with Current Literature and Conceptual Contribution of the Study

When considered in relation to the reviewed literature, the present findings occupy an intermediate position between conceptual discussions of functional food development and applied classifications of food-relevant raw materials. International sources emphasize the importance of holistic product design, the growing scientific and market relevance of functional foods, and the need to align biological functionality with consumer expectations and product feasibility (*Alongi & Anese, 2021*; *Capanoglu et al., 2024*; *Topolska et al., 2021*). Ukrainian sources, in turn, place stronger emphasis on the use of plant raw materials, the practical development of health-promoting foods and beverages, and the significance of functional ingredients under wartime, stress-related, and special-purpose nutritional conditions (*Bomba et al., 2022*; *Bomba et al., 2023*; *Stetsenko et al., 2023*; *Stetsenko, 2024*).

The conceptual contribution of the present study lies in connecting these two lines of scholarship. On the one hand, it adopts the broader international understanding of functional foods as products with scientifically meaningful added value. On the other hand, it translates this understanding into a concrete set of plant-derived ingredients that are relevant to food technologies, daily diets, and the nutritional realities addressed in Ukrainian applied research. In this sense, the study does not merely reproduce the already established idea that plant-derived compounds are important; rather, it systematizes selected ingredients as carriers of functional classes of compounds and situates them within an applied food-development perspective. This gives the study a bridging role between theoretical food-functionality discourse and ingredient-oriented product design.

Limitations of the Research

Despite its conceptual and applied relevance, the study has several limitations that should be acknowledged. First, the work is analytical rather than experimental in nature. It does not include laboratory validation of ingredient performance in specific food matrices, nor does it assess the stability of bioactive compounds during thermal processing, storage, or combined formulation. Second, the study does not provide dosage modelling or quantitative comparison of the selected ingredients in terms of concentration, bioavailability, or physiological effectiveness. Third, the functional interpretations of the ingredients are based on literature generalization and should therefore be understood as a conceptual substantiation of their relevance rather than as direct proof of the efficacy of particular products.

A further limitation concerns the level of technological specificity. Although the study demonstrates that the selected ingredients have potential practical applicability, it does not yet differentiate sufficiently between product categories, processing conditions, sensory constraints, or target population needs. Moreover, some of the physiological effects associated with particular classes of compounds in the literature may depend strongly on intake level, food matrix, long-term dietary context, and individual variability. For this reason, the present findings

should be treated as a scientifically grounded basis for subsequent product-oriented and experimental research, not as a final formulation model.

Directions for Further Research

The results of the study define several promising directions for future work. First, there is a clear need for formulation studies in which the identified ingredients are tested in specific product categories, including beverages, bakery products, snacks, sauces, desserts, and special-purpose foods. Second, future research should evaluate the organoleptic acceptability of such formulations, because the successful implementation of functional ingredients depends not only on physiological value but also on taste, aroma, texture, and consumer perception. Third, technological studies should assess the stability and retention of bioactive compounds during processing and storage, especially in systems involving heat treatment, fermentation, drying, or fat-containing matrices.

Further research should also include quantitative nutritional characterization, dosage justification, and comparative assessment of the contribution of individual ingredients to the overall functional profile of a product. In addition, studies focused on target groups—such as persons under prolonged stress, older adults, military personnel, or consumers requiring health-supportive daily diets—would make it possible to refine the practical relevance of ingredient selection. Finally, a particularly productive direction would be the development of integrated functional food models that combine several of the identified plant-derived ingredients in order to achieve complementary nutritional and physiological effects. Such work would allow the field to move from conceptual systematization toward validated product solutions with real preventive and supportive potential.

Conclusion

The present study has confirmed the growing scientific and practical relevance of plant-derived functional ingredients in the development of health food products. The conducted analytical review and systematization of contemporary scientific literature made it possible to demonstrate that the modern spectrum of functional ingredients extends far beyond the traditionally recognized categories and increasingly includes a broad range of plant-origin bioactive compounds with potential preventive and health-promoting significance. In this respect, the study supports the view that functional nutrition should be interpreted not only as a strategy of nutrient enrichment, but also as an approach to designing foods with enhanced physiological value, improved adaptive potential, and greater relevance to current nutritional challenges.

The purpose of the study, namely to analyse new classes of functional ingredients and their functional properties for further use in health food products, has been achieved. In accordance with this aim, the principal tasks of the research were completed. First, the current range of functional ingredients in modern nutrition science was characterized, and it was shown that contemporary functional food development increasingly incorporates plant-derived micronutrients and phytochemicals alongside classical ingredients. Second, the main classes of plant-based functional compounds relevant to health-promoting nutrition were identified, including phytosterols, isothiocyanates, indoles, sulfur-containing phytochemicals, lignans,

flavonoids, phenolic acids, and related compounds. Third, their major natural food sources were determined and systematized, which made it possible to establish the nutritional and raw-material basis for their inclusion in food products. Fourth, the selection of ingredients with practical relevance for health food development was substantiated, and such ingredients as flaxseed, sesame seeds, sunflower seeds, garlic, horseradish, onions, lupine flour, walnuts, hemp oil, apples, and currants were identified as promising components for the diversification and nutritional improvement of daily diets.

The results obtained in the study indicate that plant-derived functional ingredients possess a dual significance. On the one hand, they are carriers of biologically active compounds associated in the literature with antioxidant, anti-inflammatory, protective, adaptive, and other health-supporting effects. On the other hand, they are represented by food raw materials that are sufficiently accessible and technologically meaningful to be considered for practical incorporation into food systems. This combination of physiological relevance and food-technological applicability gives such ingredients particular importance for the development of health-promoting foods intended for daily consumption, preventive nutrition, and nutritionally supportive dietary strategies.

At the same time, the study has shown that the scientific substantiation of plant-derived functional ingredients should not be limited to the description of their biological activity alone. Their value becomes most significant when considered in relation to food matrices, technological feasibility, ingredient compatibility, and the broader task of creating products that are both nutritionally useful and practically acceptable. In this sense, the study contributes to the further development of the functional food concept by linking the classification of plant bioactive compounds with their natural dietary sources and their applied potential in food design.

The conducted research also confirms the practical significance of the proposed systematization for specialists in food science, nutrition, food technology, and health-oriented product development. The identified ingredients may serve as a conceptual basis for the enrichment of conventional foods, the formulation of new products with preventive potential, and the expansion of ingredient strategies in restaurant, food-service, and food-manufacturing practice. This is particularly important under conditions in which the quality of nutrition must be improved not only for general well-being, but also for strengthening the body's resistance to stress, dietary imbalance, and unfavourable environmental influences.

At the same time, the conclusions of the study should be interpreted with due regard to its analytical character. The research did not include experimental validation, dosage modelling, sensory evaluation, or technological testing in specific food systems. Therefore, the findings should be understood as a scientifically grounded conceptual basis for further applied research rather than as final evidence of the efficacy of particular food formulations. Future studies should focus on the development of product prototypes, the assessment of organoleptic and technological characteristics, the evaluation of bioactive compound stability during processing and storage, and the substantiation of effective ingredient combinations for different target groups.

Thus, the study confirms that the systematization of plant-derived functional ingredients and their natural food sources broadens the scientific understanding of health food products and

creates a meaningful foundation for the further development of nutritionally improved and functionally oriented foods.

Conflict of Interest

The author declares that is no conflict of interest.

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Appendix

Table 1. The main food sources that will be included in the diet

Groups of substances	Main food sources
Phytosterols	All unrefined vegetable oils, soybeans, oats, amaranth, vegetables, fruits
Thiols (sulfur-containing phytochemicals)	Cruciferous vegetables: all types of cabbage, radishes, mustard, horseradish, garlic, onions
Isoflavones	Soybeans and other legumes, sunflower seeds, dates, cabbage, hops
Lignans	Flax seeds, sesame seeds, bran, rye, nuts, cherries, apples, parsley, carrots, garlic
Saponins	Green vegetables, potatoes, edible green shoots from vegetables (onions, garlic, parsley, lettuce, sorrel, etc.)
Flavonoids	Berries, fruits, vegetables, citrus fruits, tea, wine, soy
Phenolic acids	Fruits (apples, blueberries, cherries, plums), potatoes, nuts, soy, coffee beans