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Review - Food/Feed Science and Technology

New Trends in the Development of Products with Probiotics, Prebiotics, Symbiotics, Paraprobiotics and Postbiotics

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HIGHLIGHTS

- Probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics used in food production.
- Benefits of consuming foods with probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics.
- Postbiotics and paraprobiotics indicate beneficial health effects that go beyond the mere presence of probiotic microorganisms.

Abstract: In recent years, the transition in the population's lifestyle, associated with healthier habits, has generated the need to consume more nutritious foods. Thus, functional foods gained space in scientific research and food industry, bringing formulations that incorporate substances such as probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics, capable of modulating the intestinal microbiota, acting positively on people's health. Considering all the benefits associated with biotic compounds, their application in everyday foods promotes new perspectives for the food market and new challenges. The processing of products containing biotic substances must maintain their appropriate proportions without interfering with sensorial characteristics of the food throughout its production cycle, storage and arrival to the final consumer in a safe way and guaranteeing its functional properties.

Keywords: Bioactivity; probiotic microorganisms; functional food; beneficial health; food technology.

INTRODUCTION

The process of scientific and technological innovation directly influenced people's quality of life, offering benefits for both the individual and society. Consequently, we observe a transition in the population's lifestyle and socioeconomic trends around the world, with consumers more attentive to nutritional issues and searching for healthier foods. Therefore, there is a need to develop new food products that are healthier, more sustainable and accessible to the population [1,2]. In this context, food went from providing essential macro and micronutrients to sustain life, to superfoods capable of promoting the prevention or even cure of various forms of disease [3].

Based on consumer needs, products were developed to promote health and well-being, creating a new food class: the functional foods [4]. The term “functional food” originated in Japan in 1984, as a way of naming “Foods for Specific Health Uses (FOSHU)”. Since its first definition, several studies have proposed a definition, the most recent describes these products as “natural or processed foods that contain biologically active compounds, which, in defined, effective and non-toxic quantities, provide a clinically proven and documented health benefit, using specific biomarkers for the prevention, management or treatment of chronic diseases or their symptoms” [5–7].

Amid the definition of functional foods, new concepts have emerged to broaden the perspectives of components that have therapeutic potential with powerful health benefits, acting to regulate the immune system, combat infections and suppress allergies and inflammations [8,9]. Elements such as probiotics, prebiotics and symbiotics, recognized as biologically active, functional and well elucidated in the literature, open advances in studies with elements now called paraprobiotics and postbiotics, which are non-viable microorganisms or metabolites capable of providing physiological benefits for human health [10]. These compounds play a crucial role in the intestinal microbiota and a diverse range of health outcomes, demonstrated to be a promising area in scientific research and food production technology [11,12]. In recent years, scientific research associated with functional foods, especially probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics, have increased and proven technological advances in both food formulation and the impact on consumer health. Therefore, this bibliographical review presents the current concepts about probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics, their effects on consumer health, as well as their functional properties and application in the food industry.

MATERIAL AND METHODS

A careful bibliographical review was carried out to identify experimental studies or literature reviews addressing the new food products development and technologies for the use of probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics with applications in food. The data was searched in the following databases: “Scielo”, “PubMed” and “ScienceDirect”. The inclusion criteria for selecting articles were: (a) articles published in English between 2019 and 2023; (b) original articles and reviews related to the inclusion of prebiotics, symbiotics, paraprobiotics and postbiotics in food and their interaction with the human intestinal microbiota; (c) Review articles on definition, health application, viability in food (included in the primary information search); (d) Book chapters on the incidence of metabolism of lactic acid bacteria with probiotic potential in plant matrices, and official websites containing relevant information. Database searches were carried out in September 2023 using the descriptors: “food products and probiotics”, “food products and prebiotics”, “food products and symbiotics”, “food products and paraprobiotics” and “food products and postbiotics”.

PROBIOTICS

Probiotics are defined as “live microorganisms that, when administered in adequate quantities, confer a health benefit on the host”. Not all living microorganisms present in foods and supplements will be classified as probiotics, but only those with a scientifically proven effect on health [13]. Within the concept of probiotics, it is possible to classify them into three categories: 'pseudo probiotic', composed of viable and inactive cells; 'ghost probiotic', dead/non-viable/inactive cells that have been ruptured; and ‘true probiotics’, active and viable microbial cells [14]. Probiotics are known by genus, species and strain. Among them, the strains of *Lactobacillus* and *Bifidobacteria* are the most used microorganisms. The bacteria *Lactococcus*, *Enterococcus* and *Bacteroides* are being studied as potential probiotics [15,16]. Other promising are the spore-producing bacteria, the most important of which are those belonging to the genera *Bacillus*, *Clostridium, Sporolactobacillus* and *Brevibacillus*. The bacterial spores are resistant to high temperatures, low pH and high pressure, which makes them ideal for food production process [17]. The bacteria classification is important, as different strains of the same species can have different effects on health [13]. Dose must also be taken into consideration for a product to be classified as probiotic and providing health benefits. For this purpose, it must contain a large number of viable cells, which is generally $>10^6$–10^8 CFU/g and be consumed at levels $>10^8$–10^{10} UFC/day [15,18,19].

Many beneficial biological effects are attributed to the consumption of probiotics, due to their modulating function, responsible for generating substrates for the host's cells and acting as an antagonist to pathogenic microorganisms, thus promoting an increase in the integrity of the intestinal barrier [20,21]. Probiotic products can be recommended for different health conditions, the three main reasons are: modulation of the immune system; suppression of pathogenic microflora; inactivation of toxins [19]. The main benefits of probiotics include to improve intestinal health and the immune system functioning, increase the bioavailability of nutrients, reduce indigestion, prevent intestinal inflammation and enhance cardiovascular health [21,22]. The intestinal microbiota also acts as a modulator in the intestine-brain axis, influencing mental health, reducing stress, depression and anxiety [23]. In addition to their beneficial action on the host's microbiota, probiotics add value and improve the nutritional and sensory characteristics of foods. They reach the consumer in the form of food products (fermentable or non-fermentable) or as dietary supplements (in powder, tablet or capsule form) [15,24]. The proven functionality of probiotics impacted the food industry and caused changes in the industrial process to meet the needs of modern consumers, who began to seek out more foods that are beneficial to their health.

PREBIOTICS

The current scientific definition for prebiotics was developed in 2016 by the International Scientific Association of Probiotics and Prebiotics (ISAPP), and remains the best accepted, defining it as: “a substrate that is selectively utilized by host microorganisms conferring a health benefit”, this definition encompasses three fundamental parts: a substance, a physiological beneficial effect and a microbiota-mediated mechanism [25]. Despite being part of dietary fibers class, prebiotics are only a subset of that, they could derive, for example, from non-fibrous substances, such as polyphenols. The main aspect of prebiotics is they are non-digestible food ingredients by the host, capable of passing through the upper part of the gastrointestinal tract (GIT) without breaking down. Instead, they are important substrates for the gastrointestinal microbiota resulting in benefits to the host [26]. Thus, for a food ingredient to be classified as a prebiotic, it must meet the following criteria [27]:

- Resistance to the acidic pH of the stomach, it cannot be hydrolyzed by mammalian enzymes and must not be absorbed in the gastrointestinal tract.
- Must be fermented by the intestinal microbiota.
- The growth and/or activity of intestinal bacteria must be selectively stimulated, and this process should improve host health.

The most common prebiotics are inulin, fructooligosaccharides (FOS), β-glucans, galactooligosaccharides (GOS), polydextrose, soybean oligosaccharides (SBOS), isomaltooligosaccharides (IMOS) and lactulose [27]. Prebiotics have a significant impact on intestinal health, they are capable of modulating the host's microbiota, promoting the increase of beneficial probiotic bacteria and inhibiting the growth of pathogenic bacteria, modulating the signaling of immunological and intestinal epithelial cells with local effects on inflammation and barrier function favoring the reduction of intestinal permeability and inflammation, in addition to improving the absorption of micronutrients such as calcium and magnesium [28]. During the fermentation process of probiotics in the GIT, metabolites such as short-chain fatty acids (SFCA) are produced, which are released by bacteria and contribute to the prevention and control of diseases, as cardiovascular issues, gastrointestinal cancer and type II diabetes, improvements in intestinal function, immune response, glucose and lipid metabolism, bone health and regulation of appetite and satiety [29,30].

Currently, the recommendation for total dietary fiber is an average daily intake of 25-35 g/day in adults [31]. There is still no exact recommendation for the dietary intake of prebiotics, studies suggest oral intake of at least 3 grams per day and around 5 grams of FOS and GOS in the daily diet confers benefits [25]. Prebiotics can be consumed as supplements or incorporated as food ingredients in baked goods, dairy products, fermented beverages, cookies, cereals, sweeteners, milk, ice cream and yogurt. In the processing of these foods, prebiotics are subject to chemical, temperature and pH stress factors, which can influence their intact delivery and activity in the colon [11,32].

SYMBIOTICS

The term symbiotic refers to the synergy or appropriate combinations of probiotics and prebiotics. Probiotics are live microorganisms that, when administered in adequate quantities, provide health benefits to the host. Prebiotics are considered non-digestible ingredients that serve as a substrate for the growth of probiotics in the human colon [33,34]. Symbiotics can be classified as complementary and synergistic. Complementary symbiotics result from a mixture of probiotic and prebiotic (that meet the criteria of their definitions) used in a dose scientifically proven to provide a health benefit. Synergistic symbiotics, on the other hand, are obtained from the mixture of a live microbe selected to use a co-administered substrate, which together lead to a health benefit for the host, the synergistic components do not necessarily need to meet the criteria of a probiotic and prebiotic [35–37].

The benefits of ingesting probiotics and prebiotics in isolation have already been scientifically validated. In addition to their isolated actions, studies have shown that symbiotic combination of probiotics and prebiotics generates an increase in intestinal bacterial diversity and promotes the release of metabolites with antibacterial, anti-inflammatory and immunomodulatory effects [33,38]. Other health effects have been reported, the microbiome alteration promotes improved glucose sensitivity, reduces the production of pro-inflammatory mediators and body fat, decreases intestinal permeability and reduces endotoxemia, acting beneficially in a series of diseases as diabetes mellitus, cancer, neurodegenerative and cardiovascular diseases and intestinal inflammation [39,40]. The ingestion of symbiotics occurs mainly through food and supplementation, thus the combination of prebiotics with probiotics promotes the improvement of their viability and effectiveness and add value to the sensorial properties [41]. The symbiotic action promotes additional preservation of probiotics in gastrointestinal conditions, with increased resistance to the host's digestive fluids improving the probiotic's survival capacity [9]. Symbiotics can be found in fermented and dairy products, raw fruits and vegetables [40].

PARAPROBIOTICS

Paraprobiotics, “ghost probiotics”, “non-viable probiotics”, “inactivated probiotics” “inanimate probiotics” are defined as inactivated probiotics or non-viable microbial cells (intact or ruptured) or even crude cell extracts which confer various technological and health benefits or "non-viable or inactivated microbial cells, which, when administered in sufficient quantities, confer benefits to the host." The prefix “para” referring to the term “paraprobiotic” originates from ancient Greek and means “side by side” or “atypical [10,42]. Paraprobiotics may be inactivated/dead/non-viable microbial cells derived from probiotics, such as teichoic acids, muropeptides from peptidoglycans, surface protruding molecules (pili, fimbriae, flagella), polysaccharides (exopolysaccharides), cell surface-associated proteins, biosurfactants bounded to the cell wall, teichoic acids, among others [43,44].

Mehta and coauthors (2023) [12] stated in a systematic review that most paraprobiotics are developed from strains of *Lactobacillus* and *Bifidobacterium*. The main advantages of using paraprobiotics observed in the literature were safety for vulnerable individuals, reduced risk of developing infections by opportunistic microorganisms, acquisition of virulence or antibiotic resistance genes and bacterial translocation. Such factors are combined with more stable compounds during food processing and storage [45]. These components can regulate the adaptive and innate immune systems. With anti-inflammatory, antiproliferative and antioxidant properties, paraprobiotics have an antagonistic effect against pathogens. In this way, greater safety stands out to guarantee technological benefits compared to probiotics [46,47].

POSTBIOTICS

Postbiotics are defined as “preparations of inanimate microorganisms and/or their components that confer a health benefit on the host” [35]. Other authors define it as products of microbial action, originating from the fermentation of carbohydrates, synthesis of enzymes, various peptides and vitamins, some of the structural components of bacteria or even low molecular weight bioactive molecules or fractions of different components derived from microorganisms[48–50]. These bioactive compounds are considered relatively new in the biotic family and are also known as bacterial or biogenic metabolites [10]. The word "biotic" is derived from the Greek word biōtikós, which means "belonging to life" and is associated with the biological ecosystem composed of living organisms and their physical environment [49,51]. The classification of postbiotics considers the composition and physiological function of the compound, including structural, peptides, teichoic acids and plasmalogens or metabolites generated by the microbiota, comprising short-chain fatty acids, vitamins and enzymes [48].

Regarding the origin of postbiotics, they result from microbial action, such as carbohydrate fermentation, synthesis of enzymes, peptides and vitamins [52]. The effects of postbiotics derive from their individual cellular components as cell wall fragments, teichoic acid, peptidoglycan and exopolysaccharide, lipids, proteins, extracellular vesicles, nucleic acids, and metabolic compounds as short-chain fatty acids, organic acids, bacteriocins and amino acids produced by bacterial cells [12]. Technical-functional limitations observed in the use of probiotics as viability control, for example, have hampered their potential applications in food products [44,53]. As a result, studies with postbiotics have attracted the industry attention due to their proven benefits when compared to probiotics and prebiotics. Among the advantages, they are more stable and safer compounds for industrial uses than probiotics [54]. Since during industrial processing, intrinsic food factors (pH, proteins concentration, fats and carbohydrates, water activity, presence of natural antibiotics) and extrinsic processing and storage conditions can influence the reduction in the viability of food and biotic cells.

Other studies indicate availability in its pure form, ease of production and storage, availability of the production process for industrial scale increase, specific mechanism of action, greater probability of triggering only responses directed by specific ligand-receptor interactions [44,55,56]. Therefore, the application of postbiotics in food products offers several technological possibilities for advancing interactions in the food matrix, as well as new products that directly affect the well-being of human health [57].

Furthermore, their application goes beyond the food industry, postbiotics can be used in the pharmaceutical and nutraceutical industries, both to promote health and prevent diseases [49]. This scope is because they have several signaling molecules that can develop antioxidant, immunomodulatory, anti-inflammatory, antihypertensive and antiproliferative effects[55,58]. Postbiotics can be a safe alternative as a treatment for human diseases and in food as an alternative to probiotics. Technological advantages in functionality are independent of cell viability. These functional ingredients would allow for longer shelf life, easier storage, handling and transportation [59]. Furthermore, postbiotics are easily absorbable, metabolizable and excretable by different organs and tissues of the host, offering the same benefits as probiotics without incurring risks from interactions with a living organism [49,60].

DEVELOPMENT IN THE FOOD MARKET

The demand for so-called “healthier” and “good for the body” foods has increased, making it necessary to develop new products to satisfy the consumer’s dietary needs, offering more technological products, beneficial substances and foods with claims of functional properties associated with prevention and improvement in health when consumed [4,61]. According to data collected from research in the database (Table1), the volume of scientific production associated with the theme “food production” for “probiotics”, “prebiotics”, “symbiotics”, “paraprobiotics” and “postbiotics” has increased every year.

Table 1. Comparison between the number of publications associated with the terms “food production” for probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics between the years 2019 to 2023.

Year	Probiotics	Prebiotics	Symbiotics	Paraprobiotics	Postbiotics
2019	1331	728	102	10	13
2020	1677	954	102	4	21
2021	1984	1104	142	15	38
2022	2240	1198	147	10	67
2023	2233	1158	117	9	73

The development of products related to probiotics and prebiotics are the most studied and together they correspond to 94% of research articles, probably due to their already known functional properties. Although there are still few studies related to symbiotics, paraprobiotics and postbiotics, it is possible to see the progress in research and discoveries of new formulations of highly functional and beneficial products for the consumer. Most investigations into probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics include complete reviews on new concepts and advances in relation to the advantages proposed with the new nomenclature. When analyzed individually, it is possible to notice an increase in the demand for studies associated with the topic over the years, both in application in food and in the association of consumption and health benefits (Figure 1).

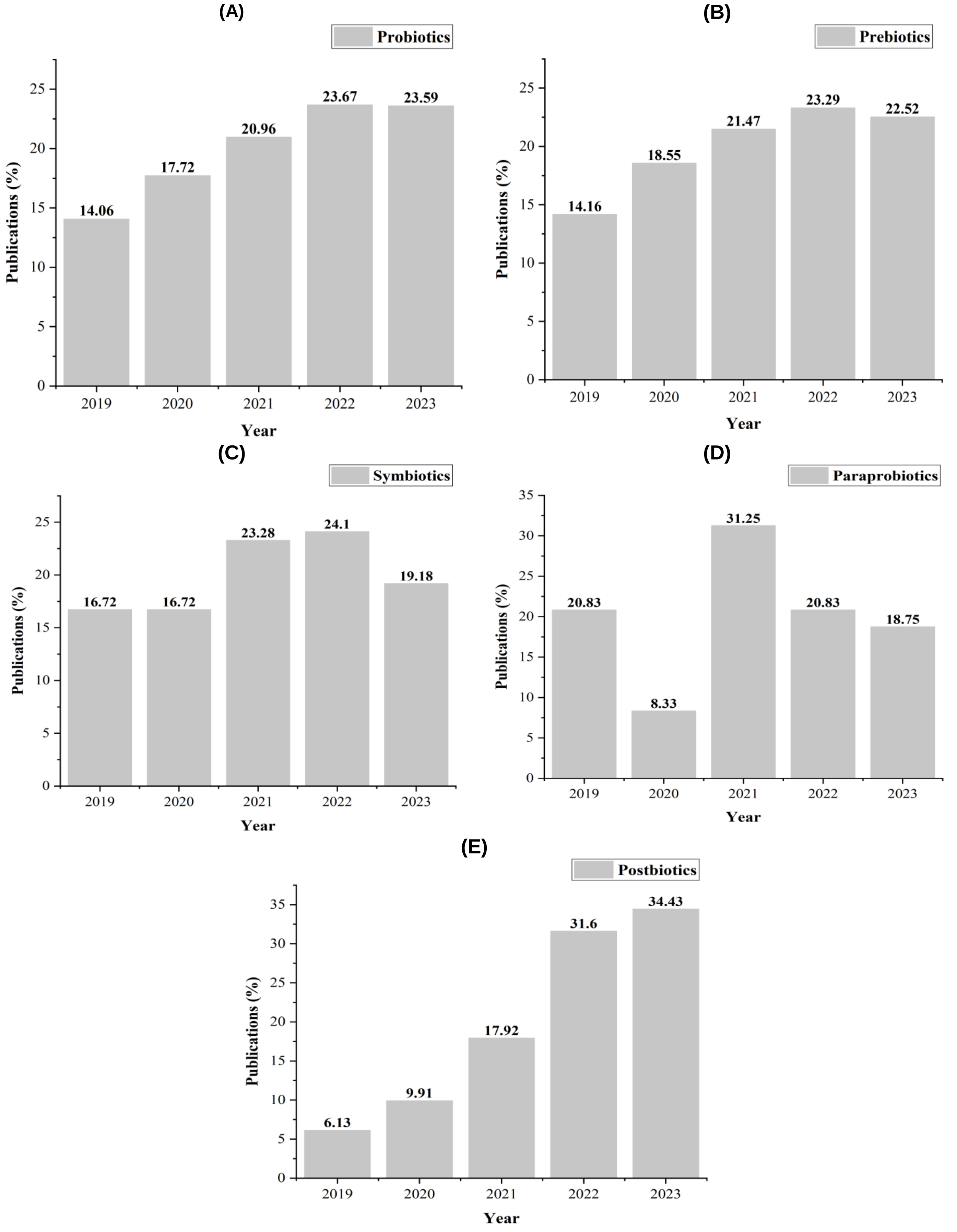

Figure 1. Percentage of publications related to the themes probiotics (a), prebiotics(b), symbiotics(c), paraprobiotics(d) and postbiotics(e) between the years 2019 to 2023.

The innovation process in the food industry brings a more scientific and technical approach to the production of industrialized foods, reformulating food production techniques already available on the market or introducing new foods with claims of functional properties [32,62]. Healthier and more sustainable foods have a positive impact on human health. The literature generally indicates that the consumption of food products with health and well-being claims is higher in developed societies as they have already gone through the nutritional transition, which involves a sequence of three stages: first, expansion of caloric consumption through the provision of cheaper plant-based food products; second, replacement of plant-based food products with animal-derived products; thirdly, purchasing food products for the benefits they directly provide to individuals and the way they fit into their personal values [4].

Processing, together with diet and formulation, plays a fundamental role in the functionality of foods [6]. When formulating probiotic products, the main challenge is to ensure the survival of microorganisms during processing and storage, as well as preventing undesirable interactions with the food matrix so that it can provide the health benefit, until the end of the shelf life [11,19,63]. The main prebiotics frequently used in the food industry are: fructooligosaccharides (FOS), galactooligosaccharides (GOS) and transgalactooligosaccharides (TOS), and recent studies have identified the potential of legumes and legume-based food products to serve as a prebiotic matrix [64,65]. The symbiotic action resulted from the incorporation of prebiotics and probiotics in food improves microbiological stability and guarantees longer shelf life by ensuring a minimum number of viable cells, however, this addition does not affect the organoleptic properties of the final product [66].

In food processing, paraprobiotics have greater stability, this contribute to a longer shelf life and safety during industrial handling because they can be worked in a wide temperature range, have little or no interaction with the components of the food matrix and allow the addition of probiotics to the food product before heat treatment [10,67].

Postbiotics also present greater flexibility and stability when added to foods, act as preservatives and antimicrobials, and are promising natural components for the food industry. In practice, postbiotics are more stable and safer for food use than the live bacteria from which they are produced [68,69]. Amid continuous innovations in functional foods that feature probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics in their formulations, these substances have been increasingly incorporated into food matrices, including dairy products, grains and fruit juices. Table 2 lists the main applications and benefits of these biotic compounds in the food industry.

Table 2. Selected publications (2019–2023) on foods containing probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics.

Classification	Treatment	Concentration	Food/ Benefits	Ref
Probiotic/ prebiotic	Incorporation of inulin, oligosaccharides and *Lactobacillus paracasei*	3.5% inulin; 0.5% succinoglycan oligosaccharides; 3.0% inulin and 0.5% succinoglycan oligosaccharides and *Lactobacillus paracasei* with counts above 10^8 CFU mL^{-1}	Functional fermented drink from soy and rice, with probiotic resistance during exposure to simulated gastrointestinal conditions, reduction of syneresis.	[70]
Probiotic/ prebiotic/ symbiotic	Bacterial fermentation of goat and cow milk	Cow's and goat's milk with added kefir, *Lactobacillus acidophilus* LA-5, *Bifidobacterium bifidum* BB-11 and inulin	Kefir with synergistic symbiotic properties.	[71]
Probiotic/ prebiotic/ symbiotic	Vegetable drink fermentation	FOS (2.5% w/v), pectin (0.5% w/v), *Lactobacillus casei* 6.50 log CFU g -1 (proportion of 0.10 g of culture for 1.00 L of NFD)	Symbiotic non-dairy coconut-based drink. Product with functional claims, classified as symbiotic and synergistic. Claim of “clean labels” without preservatives.	[72]
Symbiotic	Prebiotic and probiotic encapsulation	Product 1: 0.5 g of pigmented rice powder + probiotic cells in a ratio of 1:9; Product 2: stingless bee honey + probiotic cells in a 9:1 ratio; Product 3: pigmented rice powder + stingless bee honey + probiotic cells in the proportion (1:6:3)	Symbiotic product containing pigmented rice and/or stingless bee honey and probiotic cells. Symbiotic product could be used as a therapeutic or functional food to replace antibiotics.	[73]

Cont Table 2

Probiotic	Yogurt fermentation	*Lactobacillus elbrueckii* subsp. Bulgaricus and *Streptococcus thermophilus* and the probiotic culture *Lactobacillus acidophilus*, both at a concentration of 1% (v/v) and 10^{12} CFU/mL.	Probiotic whole milk yogurt. improvement in the development, optimization and reliability of processes for dairy products.	[74]
Probiotic	Vegetable drink fermentation	Five different proportions of UHT milk and soy drink (100:0, 75:25, 50:50, 25:75, 0:100) and 0.1 g of probiotic cultures and 0.07 g of yogurt culture in 100 mL	Functional probiotic drink with a high content of bioactive components, mineral elements, significant nutritional and organoleptic properties	[75]
Probiotic	Vegetable drink fermentation	Date juice (4% v/v, inocula/juice) Viability of *L. acidophilus* La5 and *L. sakei* were 7 x 10^6 and 2.2 x 10^8 CFU/mL, respectively.	Fermented date juice with probiotic and phytochemical properties	[76]
Probiotic	Develop probiotic smoothie drink	Mixed probiotic culture (*Bifidobacterium longum B. infantis* and *B. breve*) and thermophilic culture (*Streptococcus thermophilus, Lactobacillus delbrueckii* subsp. Bulgaricus); skim powdered milk; pasteurized skimmed milk (Xandô); pasteurized fruit Pulp.	Probiotic smoothie with adequate levels of probiotics for health claims and can be considered a functional product.	[77]
Probiotics/ paraprobiotics	Fermentation of reconstituted skimmed milk powder added with probiotics and paraprobiotics	Reconstituted skimmed milk powder *Streptococcus thermophiles* and *L. delbrueckii* ssp. bulgaricus, as well as probiotic cultures (*L. acidophilus* + *B. lactus, L. acidophilus* or *B. lactis*) plus paraprobiotics (dead *L. acidophilus* + dead *B. lactis*, dead *B. lactis* or dead *L. acidophilus*).	Probiotic and paraprobiotic yogurt. Product with good rheological characteristics and viscosity.	[42]
Probiotics/ paraprobiotics	Fermentation of whey and grape juice	50 g of whole grape juice, 49.89 g of reconstituted whey powder and 0.11 g of guar gum, 0.1 g/L of the probiotic culture *L. casei* subsp. paracasei	Grape-flavored whey paraprobiotic drink. Demonstrated hypoglycemic activity both in vitro by inhibiting α-glucosidase and α-amylase	[45]
Probiotic/ prebiotic/ postbiotic	Pro-pre- and postbiotic fermentation of dietary dairy matrix with prebiotic sugar substitutes	Reconstituted skimmed powdered cow's milk. Probiotic cultures containing *L. acidophilus*(L) and *B. animalis* subsp. lactis(B), stevia and inulin	Functional yogurt. Using inulin with stevia is more effective than stevia alone in increasing probiotic bacterial viability and postbiotic SCFA production.	[78]
Probiotic/ symbiotic	buffalo milk yogurt incorporated with bael fruit pulp (Aegle marmelos)	Yogurt, bael fruit pulp5% (w/v). Probiotic culture *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. bulgaricus in a 1:1 ratio	Bael yogurt. The use of 5% bael incorporation provides an ideal combination for probiotic/symbiotic product development.	[79]

The main applications in food are associated with the production process of fermented drinks, whether from animal or vegetable origin or a combination of both. In the production of fermented milk or yogurt, the viability of products enriched with probiotic strains and/or synergism of biotic substances in the final quality of the product was evaluated. The products obtained showed good acceptability, adequate organoleptic characteristics and resistance to processing and storage within the parameters considered suitable for functional foods [42,71,74,79]. The fermentation used in these products imparts an acidic flavor, which may be in greater or lesser concentration depending on the processing [80]. This characteristic can be beneficial when it produces an expected flavor or negative when the acidity level is high, in this case it is possible to modify/improve the flavor by adding fruit. Although the results may vary depending on the interaction between the different strains and the type of fruit, enrichment with fruits generates greater acceptance by the consumer, since the acidic flavor is attenuated [81].

It is possible to notice the improvement in the acceptance and stability of biotic compounds in the studies by Gallina and coauthors (2019) [77] that produced a red fruit flavored smoothie drink and achieved greater acceptance and sensory preference, in addition to being able to maintain probiotic levels to provide health benefits to the consumer. Yapa and coauthors (2023) [79] also developed a dairy product incorporated with fruit pulp, obtaining good acceptability of buffalo milk yogurt added with bael. It proved that the addition of 5% bael is ideal for the development of symbiotic products. Barros and coauthors (2021) [45] used whey to produce a grape-flavored paraprobiotic drink and observed good acceptability and proved the reduction in postprandial glycemia in healthy individuals. In addition to incorporating fruits into fermented dairy products, fruit juices/pulp can serve as an alternative means in the production of functional drinks, other vegetables such as legumes and oilseeds also show a good response to the fermentation process [70,72,75,76].

CONCLUSION

The scientific and technological development of the food industry has been growing over the years, leading to the creation of new, increasingly functional products, rich in beneficial substances to the health of the consumer. There are several formulations that incorporate substances such as probiotics, prebiotics, symbiotics, paraprobiotics and postbiotics in daily food products, driving the development of the functional foods market. Biotic substances are proven to be beneficial to the human health, the science has proven their potential in modulating the immune system, suppressing pathogenic microflora and inactivating toxins.

In addition to the health benefits, studies have brought innovations to the food manufacturing process, incorporating these biotic components into food formulations already known to the consumer. The main applications in food are associated with the production process of fermented beverages to increase the quality while maintaining the rheological and organoleptic characteristics of the product as well as the stability throughout the production, storage and consumption of these products. Studies associated with probiotics, prebiotics and symbiotic are available in greater volume, enabling a better understanding of the action of these substances on food and intestinal flora, while paraprobiotics and postbiotics present a smaller volume of studies, showing the need for more analyses.

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