

Review

Functional Yogurt: Types and Health Benefits

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Abstract: In the past decade, the increasing interest in healthy consumption has encouraged the development of functional products in the yogurt sector. Dairy products are extensively used in the production of functional foods because of their excellent and versatile technological properties. Among dairy products, yogurt is one of the dairy foods that has been most widely used to deliver bioactive compounds to consumers. The market features various types of functional yogurt, including probiotic, prebiotic, synbiotic, high protein, lactose free, and novel products known as easy-to-digest yogurt. The added ingredients in these products influence the structural, nutritional, and functional properties of yogurt. These effects vary depending on the chemical and biological characteristics of each ingredient. Additionally, during fermentation, the added substances can impact the number and viability of the bacteria involved, affecting the quality of the products during storage. Furthermore, the consumption of functional yogurt is associated with various health benefits. These benefits are linked not only to supporting health but also to altering the course of a disease or alleviating symptoms. This review article discusses functional yogurt and its health effects, incorporating recent studies.

Keywords: yogurt; probiotic; prebiotic; synbiotic; functional food; functional yogurt; health



Citation: Sarıtaş, S.; Mondragon Portocarrero, A.d.C.; Miranda, J.M.; Witkowska, A.M.; Karav, S. Functional Yogurt: Types and Health Benefits. *Appl. Sci.* **2024**, *14*, 11798. <https://doi.org/10.3390/app142411798>

Academic Editor: Marco Iammarino

Received: 7 October 2024

Revised: 29 November 2024

Accepted: 13 December 2024

Published: 17 December 2024



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1. Introduction

With increasing interest and concern regarding healthy nutrition, a more conscious consumer profile is emerging [1,2]. This awareness among consumers is driving the development of the nutritional and functional properties of products in the food sector and fostering the creation of diverse new products [3]. Functional foods are defined as those that provide health benefits beyond basic nutritional values [4,5]. These foods are recognized for their potential to offer different health benefits, including antioxidant properties, anti-inflammatory effects, digestive system support, immune system enhancement, heart health improvement, or the prevention of cardiovascular and chronic diseases [6,7].

Milk and dairy products are prominent in the functional food sector because of their contents of fats, proteins, carbohydrates, minerals, and vitamins [8,9]. Milk contains both micronutrients and macronutrients, including various bioactive compounds, especially lactoferrin, immunoglobulins, lactoperoxidase, and oligosaccharides [10–13]. The health benefits associated with enhancing the characteristics of these components have been investigated in numerous studies [14,15]. In particular, glycoproteins play significant roles, such as modulating immune responses by demonstrating antibacterial and antiviral capacities and exerting neuroprotective effects against neurological diseases [16–19]. In terms of these functions, the importance of consuming milk and dairy products is highlighted.

At this point, yogurt can be considered one of the most essential dairy products because of its rich bioactive content [20,21]. This food is obtained by enhancing the functional and

nutritional properties of milk through fermentation [22–24]. Owing to fermentation, the content and nutritional properties of milk, along with its sensory properties, primarily its texture, are modulated [25]. In addition to the benefits provided by milk, yogurt has additional characteristics [26,27].

Over the past decade, the production of different types of yogurts has increased. Probiotic, prebiotic, and synbiotic yogurts are widely produced and consumed, notably to support gut health and the digestive system [28–31]. In addition, yogurt is produced from different materials to support various functions [32–34]. For example, plant-based materials, including fruits, vegetables, leaves, grains, seeds, or various food additives, are used to produce different kinds of yogurt [35,36]. Additionally, for consumers who have issues with consuming milk and dairy products, lactose-free and easy-to-digest products are also being produced [37]. In this context, yogurt made from A2 milk, known as the natural form of milk, presents a new approach to functional yogurt types [38].

With the growing interest in the consumption of functional foods, the health benefits and functionalities of food products are determining factors in consumers' decisions to choose or reject certain products [39]. With the addition of certain materials, functional yogurt not only provides a range of health benefits to consumers through the fermentation of milk but also enhances these benefits [23]. Among components beneficial to human health that may be included in yogurt are probiotic bacteria, dietary fibers, which are considered prebiotics; various fruits and vegetables; and other plant parts, such as leaves and seeds [40,41]. Thus, yogurt with an enhanced functional content can benefit gut health, the digestive system, and other systems [7,42–46]. Additionally, these foods have been found to exhibit antioxidant, anti-inflammatory, and antidiabetic properties.

In this sense, the evolution of yogurt from the past to the present and the various types of functional yogurt have been investigated. Additionally, the effects of yogurt consumption on both healthy and diseased individuals have been extensively examined.

2. Functional Yogurt Types

Over time, yogurt has been produced in various forms to meet different demands and needs. The primary reason for the development of these types of yogurts is to emphasize the nutritional and functional properties of yogurt (Table 1). In this context, the addition of probiotics and/or prebiotics in yogurt production has led to the creation of probiotic, prebiotic, and synbiotic yogurts [47,48]. The consumption of these products is especially common for improving and regulating gut health [49]. Additionally, the supplementation of fruits, vegetables, and various grain products in yogurt production is widespread [50]. Dairy products such as colostrum are also included in production because of their rich bioactive content [51–53]. Each of these ingredients imparts specific properties to yogurt and promotes its functionality. For individuals with high protein needs, such as athletes, high-protein yogurt is considered a healthy choice. Finally, lactose-free and easily digestible yogurt products are being developed for those who have difficulty consuming milk and dairy products [54]. Additionally, the bioaccessibility and bioactivity of these added substances are evaluated via in vitro digestion models [55].

Table 1. Functional yogurt products.

Types of Functional Yogurt	Effects	Added Components	References
Probiotic yogurt	- Enhance texture and rheological and sensory properties	<i>Lentilactobacillus kefirifaciens</i> <i>Kluyveromyces marxianus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Lactiplantibacillus plantarum</i> <i>Limosilactobacillus reuteri</i> <i>Lacticaseibacillus casei</i> <i>Limosilactobacillus acidophilus</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	[56–63]

Table 1. Cont.

Types of Functional Yogurt	Effects	Added Components	References
Probiotic yogurt	- Exhibit antioxidant, antimicrobial antibacterial, and antifungal activity	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Lactiplantibacillus plantarum</i> <i>Lactobacillus gasseri</i>	[4,11,26,55,64,65]
	- Enhance improvement of stability	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Lacticaeibacillus casei</i> <i>Lacticaeibacillus rhamnosus</i> <i>Lactiplantibacillus plantarum</i> <i>Lacticaeibacillus rhamnosus</i>	
	- Enhance physicochemical properties	<i>Lactococcus lactis</i> subsp. <i>lactis</i> <i>Limosilactobacillus acidophilus</i> <i>Lacticaeibacillus casei</i> <i>Bifidobacterium bifidum</i>	
	- Exhibit alteration of metabolomic profile	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Lacticaeibacillus casei</i>	
	- Enhance product quality	<i>Lactiplantibacillus plantarum</i> <i>Lacticaeibacillus casei</i>	[66,67] [68] [69]
Prebiotic	- Enhance the bioactive content	Lactosucrose Prebiotic from guava puree byproducts Inulin	[48] [70–75]
	- Enhance the textural, rheological, and sensory properties	Polydextrose Xylooligosaccharide Oligomeric isomaltose Galactooligosaccharide Tragacanth gum Chitooligosaccharide Fructooligosaccharide	
Synbiotic	- Enhance the physicochemical and textural properties - Enhance the rheological and sensory properties	<i>Lacticaeibacillus rhamnosus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Limosilactobacillus acidophilus</i> <i>Lactobacillus</i> spp. <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Limosilactobacillus fermentum</i> <i>Lacticaeibacillus paracasei</i> <i>Levilactobacillus brevis</i> <i>Lacticaeibacillus casei</i> <i>Lactobacillus gasseri</i>	[1,2,20,25,29,47,76–83]
		Banana fiber Banana peel fiber Lactitol Inulin Maltodextrin Oligofructose or polydextrose β -glucan Hi-maize Iranian grape syrup <i>Malva neglecta</i> Lactulose	
	- Enhance gastric digestion resistance	<i>Limosilactobacillus acidophilus</i> Xylooligosaccharide <i>Limosilactobacillus acidophilus</i> and their bacteriocins <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Levilactobacillus brevis</i> <i>Bifidobacterium longum</i> <i>Bifidobacterium bifidum</i>	[84] [85–90]
	- Enhance shelf life - Enhance product quality	<i>Propionibacterium freudenreichii</i> <i>Propionibacterium freudenreichii</i> subsp. <i>shermanii</i> Xanthan gum Fructooligosaccharides Galactooligosaccharide Lactitol Inulin	

Table 1. Cont.

Types of Functional Yogurt	Effects	Added Components	References
Synbiotic	- Enhance the bioactive content	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Propionibacterium freudenreichii</i> spp. <i>shermanii</i> <i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium</i> spp. Inulin	[22,91]
Fortified/functional ingredient added	- Enhance product quality	Xanthan Gum Sweet pepper extract <i>Panax notoginseng</i> Saponins Green-banana biomass Cumin essential oil Vitamin C Vitamin D Nano casein–pectin complex Water chestnut (<i>Trapa bispinosa</i>) starch Mango pulp Pomegranate peel Moringa aqueous extract Persian shallot (<i>Allium hirtifolium</i> Boiss) Banana pulp L-Glutamine Quercetin	[92–97]
	- Enhance physicochemical, textural, and sensory properties	Slippery elm bark Marshmallow root N-acetyl-d-glucosamine Licorice root Maitake mushrooms Zinc orotate Aloe vera gel drink Vitamin D3 Riboflavin (vitamin B2) Carob flour Nanoliposomes containing bitter melon extract Curcumin-loaded nanoparticles Exopolysaccharides Bee pollen	[6,21,41,50,98–105]
	- Exhibit antioxidant, anti-inflammatory, antibacterial, and emulsification effects	Bawang dayak (<i>Eleutherine palmifolia</i>) extract Clover sprout protein ZnO nanoparticles Aloe vera gel Curcumin Carrot waste extract Agave tequilana aqueous extract Whey protein Caseinate Okra (<i>Abelmoschus esculentus</i>) mucilage Lactoferrin	[32,36,106–111]
	- Enhance the bioactive content	Bael (<i>Aegle marmelos</i>) fruit pulp Loquat (<i>Eriobotrya japonica</i> L.) marmalade Mango (<i>Mangifera India</i> L.) juice Pomegranate (<i>Punica granatum</i> L.) juice <i>Isochrysis galbana</i> Whey protein-based nanoformulation	
High protein	- Enhance physicochemical properties - Exhibit ACE inhibitory activity	Calcium caseinate	[23,40,112–119]
Lactose-free	- Enhance the bioactive content	Whey β -galactosidase	[120]
	- Enhance the physicochemical, rheological, textural, and sensory properties	β -galactosidase Inulin Oligofructose Whey	[37,121–123]
	- Enhance product quality	β -galactosidase Fructooligosaccharides	[124]

2.1. Probiotic

Probiotics are live microorganisms that provide beneficial effects on health, primarily by supporting the digestive system [39,61]. The consumption of these microorganisms, defined as live microbial food supplements, is generally considered safe [67]. Probiotics can modulate the gut microbiota, enhance digestive health, and support the immune system [64]. Studies have demonstrated that food products must contain a minimum of between 10^6 and 10^7 CFU/mL probiotics to benefit from these advantages [56,60]. *Lactobacillus* and *Bifidobacterium* species are prevalent in yogurt production [47,59]. *Streptococcus salivarius* subsp. *thermophilus* (*S. salivarius* subsp. *thermophilus* and *L. delbrueckii* subsp. *bulgaricus*) are commonly used as starter cultures in yogurt production [125]. During fermentation, they facilitate the conversion of lactose into lactic acid through processes such as glycolysis, lipolysis, and proteolysis. This starter culture promotes the viscous texture of the products [126]. Studies have investigated the use of diverse probiotic species in yogurt production [63]. The probiotic strains used in production affect the properties of yogurt. Therefore, the choice of probiotic is a crucial parameter for production [4].

Live probiotics in yogurt are referred to as bioyogurt because of their effects. Probiotics not only provide health benefits but also improve the physicochemical, textural, and sensory properties of the main product [57]. This is primarily due to the exopolysaccharides (EPS) produced by the probiotics, as well as the starter cultures [65,127]. These polysaccharides, which are secreted outside the cells by probiotics, positively affect the textural properties of the yogurt, including viscosity, gel structure, stability, and smoothness, as well as the sensory properties such as mouthfeel, taste, and aroma [106,127]. The probiotics generally used in fermented food production support the structure of functional yogurt by producing EPS [86]. Commonly, yogurt products have high acidity and low pH values, making it unlikely that they provide suitable conditions for the viability of probiotics during passage through the digestive system [36]. Using the yogurt matrix for probiotic delivery and ensuring probiotic viability and stability is essential [55]. The survival of these bacteria during the digestive process demonstrated that they can contribute to beneficial bacterial populations in the digestive system.

A recent study assessed the effects of *Lentilactobacillus kefiranofaciens* (*L. kefiranofaciens*) and *Kluyveromyces marxianus* (*K. marxianus*), probiotic microorganisms isolated from kefir grains, on yogurt fermentation as mono- and cocultures [57]. The results of yogurt production demonstrated that, when only *L. kefiranofaciens* was used in a monoculture, the yogurt produced tended to have a low viscosity. Consequently, these yogurt samples presented weaker gel structures and greater whey separation. On the other hand, co-culture with both microorganisms increased microbial aggregation, biofilm formation, and exopolysaccharide production, increasing nutritional stability. Additionally, it resulted in yogurt with higher viscosity, strengthening the gel structure and reducing whey separation. Additionally, *L. kefiranofaciens* and *K. marxianus* exhibited similar survival rates in digestive fluids when used alone and together, indicating that these bacteria could be effective as probiotics.

A study by Gkitsaki et al. aimed to examine a new yogurt production method by adding the probiotic bacterium *Lacticaseibacillus rhamnosus* (*L. rhamnosus*) to conventional yogurt and to compare the antioxidant capacity, performance during storage, and sensory properties of this yogurt [55]. The probiotic yogurt was more acidic than conventional yogurt, but there was no significant difference at the end of the storage period. *S. salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (*L. delbrueckii* subsp. *bulgaricus*), used in both yogurts, did not survive after the in vitro digestion model. However, *L. rhamnosus* contained in the probiotic yogurt survived during postdigestion transit. Additionally, compared with conventional yogurt, probiotic yogurt was found to have greater phenolic content and antioxidant activity. Sensory evaluation results indicated that the probiotic yogurt had a better appearance, but no significant differences were observed for the other sensory parameters.

In a study conducted in 2023, a rich probiotic yogurt starter culture was developed using *L. delbrueckii* subsp. *bulgaricus* and *Lactiplantibacillus plantarum* (*L. plantarum*), and

probiotic yogurt production and storage were carried out with these cultures [4]. This study investigated the inhibitory effects of these two species on *Escherichia coli* (*E. coli*), *Kluyveromyces lactis* (*K. lactis*), *K. marxianus*, and *Saccharomyces cerevisiae* (*S. cerevisiae*). Yogurt products produced with *L. delbrueckii* subsp. *bulgaricus* significantly inhibited the growth of *E. coli*, while the same effect was not observed for the other species. Both lactic acid bacteria inhibited the growth of *K. lactis*, *K. marxianus*, and *S. cerevisiae* yeasts, with the strongest effect observed in *L. delbrueckii* subsp. *bulgaricus*. Additionally, there was no statistically significant difference in the water-holding capacities of the samples. However, the syneresis rates decreased during the storage period. Moreover, the viscosity values of the samples increased during storage. The total lactic acid bacteria count in the samples significantly increased during the storage period, indicating that the bacteria remained viable and active throughout this period. No significant differences were found in the rheological or sensory parameters of the produced samples. In a similar study conducted by Yang and Yoon, the effects of different probiotic lactic acid bacteria on the physicochemical properties, viscosity, antimicrobial effects, and consumer preferences of yogurt were evaluated [65]. The results revealed that, during the storage period, the pH values of all of the samples decreased, whereas the titratable acidity increased. The highest viscosity was observed in the samples containing *L. plantarum*. Additionally, enterohemorrhagic *E. coli* survival tests showed that the fourth yogurt sample significantly reduced the survival time of the bacteria, indicating a higher antimicrobial activity than the other ones. Additionally, the first sample prepared with only the yogurt starter culture presented the lowest antimicrobial activity. According to the consumer test results, although there was no significant difference in the taste scores among the samples, the fourth yogurt sample containing *L. plantarum* and *L. gasseri* received the highest scores for sourness, overall acceptability, viscosity, texture, and mouthfeel. In this context, the combined use of *L. plantarum* and *L. gasseri* enhances both the probiotic and sensory properties of yogurt. In conclusion, studies revealed that the type of bacteria added during functional yogurt production directly affects the properties of the final product.

To benefit human health, probiotic bacteria need to survive and maintain their viability during passage through the gastrointestinal system. Encapsulation methods for preserving probiotic bacteria are extensively applied in the food, pharmaceutical, and supplement industries [128]. In one study, the effects of different encapsulation methods on the viability of the probiotic bacteria *L. rhamnosus* and *L. plantarum* in yogurt and the physicochemical and sensory properties of yogurt samples were examined [66]. The results demonstrated that the pH values of all the samples decreased during storage, but the pH of the encapsulated bacteria decreased less than that of the free forms. The acidity values increased during storage, with free bacteria showing greater acidity than encapsulated bacteria. The samples encapsulated in the multilayer emulsion had the highest viscosity, followed by those encapsulated in the conventional emulsion and those in the free emulsion. Notably, the sample with *L. plantarum* encapsulated in the multilayer emulsion had a higher viscosity than the sample with *L. rhamnosus*. Additionally, the encapsulation methods improved the syneresis and water-holding capacity of the products. The viability of the probiotic bacteria was evaluated via various methods, and it was concluded that the samples encapsulated with multilayer emulsions had relatively high encapsulation efficiencies and greater viability. Sensory analysis results indicated that the form of encapsulated probiotic bacteria did not differ noticeably from the free form in terms of taste, smell, appearance, or texture, as perceived by consumers [66]. Similarly, in another study investigating the effects of different encapsulation methods on the viability, physicochemical, and sensory properties of *Bifidobacterium animalis* subsp. *lactis*, it was found that encapsulated probiotics resulted in greater viability in yogurt than free probiotics did [58]. Additionally, compared with encapsulated probiotics, free probiotic bacteria undergo a faster fermentation process, and encapsulated probiotics, in turn, have a shorter fermentation process than traditional probiotics. When evaluating product quality, yogurt containing encapsulated probiotic bacteria was characterized as having the best values in terms of viscosity and texture.

In conclusion, the encapsulation method used resulted in significant differences in the properties of the products.

Drying methods are also techniques used to preserve the health benefits of probiotics at high viability [69,100,129]. In an article where free and spray-dried *L. plantarum* bacteria were used during yogurt production, the addition of spray-dried *L. plantarum* resulted in increased viability of the bacteria in the yogurt [69]. Similarly, another study demonstrated that the freeze-drying technique can help probiotics remain alive during yogurt production [100].

In summary, probiotic yogurt is superior to traditional yogurt both nutritionally and functionally. The use of various probiotics enhances the textural, physicochemical, and sensory properties of the product. At this point, the viability and functionality of probiotics are important, and various techniques can improve these characteristics. The microencapsulation method, in particular, offers a suitable approach to enhance the stability and viability of probiotic bacteria in the yogurt matrix. The type of probiotic used and the fermentation efficiency are highly important.

2.2. Prebiotic

Prebiotics that have a nondigestible function and are selectively fermented in the intestine contribute to maintaining, balancing, and promoting the development of the gut microflora when added to yogurt production [70,71]. In addition to their health benefits, they also help improve the rheological and sensory properties of the product [73]. The generally used prebiotics include fructooligosaccharides (FOSs), galactooligosaccharides (GOSs), inulin (INU), polydextrose (PDX), and xylooligosaccharides (XOS) [81]. Adding one or more of these factors enhances the functional properties of the product [72]. Determining which prebiotics to integrate and at what dosage are parameters that influence and need optimizing for product characteristics. Additionally, researchers have conducted numerous studies to evaluate food byproducts from fruits, vegetables, and grains as health-supporting food additives, supporting zero-waste policies [70].

INU and PDX were added to yogurt to examine their physicochemical and sensory properties in a study conducted by Dias et al. [71]. While no significant difference in texture was observed in the yogurt prepared with PDX, those with added INU showed a decrease in texture properties during storage. Similarly, in sensory evaluation, PDX-added products were perceived similarly to the control, whereas those with INU were rated lower in acceptance levels. Conversely, when probiotic survival was evaluated, the yogurt with INU presented increased probiotic survival during storage, whereas overall, all of the yogurts maintained minimum probiotic survival throughout the storage period.

In a recent study by Li et al., FOS, GOS, INU, PDX, and XOS prebiotics were added to yogurt in equal dosages to investigate their effects on the textural and rheological properties of products [130]. INU, XOS, and PDX had the strongest influence on the rheological, textural, and water-holding characteristics of yogurt, whereas GOS and FOS had less of an impact on these properties. These varied effects highlight the importance of careful selection when adding prebiotics to yogurt.

When developing prebiotic-added yogurt, the type and dosage of the added prebiotics are crucial. For example, one study investigated the physicochemical and sensory properties of yogurt supplemented with different amounts (3%, 6%, 9%, 12%, or 15% *w/w*) of INU [75]. The results showed that, as the amount of INU increased, the total acidity of the product decreased, whereas the pH increased. These findings indicate that, while INU supplementation enhances the nutritional value of yogurt, the optimal dosage needs to be optimized.

Under the zero-waste policy, components derived from food waste and byproducts can be utilized as prebiotics in functional yogurt production [45]. One study evaluated the prebiotic properties of byproducts obtained from guava fruit and their utilization in yogurt production [70]. Enzymatically processed guava byproducts significantly promoted the growth of *Lactobacillus* spp. in prebiotic-supplemented yogurt, demonstrating that

Lactobacillus spp. are suitable nutrient sources for probiotic bacteria. Additionally, guava byproducts were found to enhance the textural properties of yogurt. This study serves as a significant example for the evaluation of food byproducts.

In summary, the addition of prebiotics to yogurt products enhances both their rheological and sensory properties to support health. Additionally, the materials derived from food waste and byproducts can serve as prebiotic sources, contributing to zero-waste policies.

2.3. Synbiotic

Synbiotic yogurt, which includes a combination of probiotics and prebiotics, is a novel approach. It is believed that probiotics consume prebiotics as a nutrient source, thus maintaining and enhancing their viability and growth [79,81]. The nutritional value of the products produced through the synergistic relationship of probiotics and prebiotics is enhanced, and their functional properties are promoted [87,88]. These compounds may increase the amount of bioactive components [22,91]. On the other hand, the textural, rheological, sensory, and structural properties of yogurt are also believed to be improved through the use of synbiotics [80,82,90]. In this context, prebiotics, probiotics, or both can be added to yogurt in free or encapsulated forms [84].

In a study reported by Hussien et al., the probiotic *Limosilactobacillus acidophilus* (*L. acidophilus*) was added along with FOS and INU prebiotics during yogurt production [85]. The addition of INU and FOS as prebiotics extended the shelf life of the samples. The microbiological evaluation results revealed that the INU and FOS increased the number of yogurt starter cultures during storage. In addition, some samples containing bacteriocin could increase the microbiological quality by controlling the number of yeasts and molds under control. Sensory evaluation results indicated that the addition of INU could positively affect the mouthfeel and taste profile of yogurt.

El-Kholy et al., aimed to assess the functional and sensory properties of synbiotic bioyogurt enriched with types of INU isolated from chicory and globe artichoke roots [77]. When the physicochemical properties were evaluated, the two novel types of INUs exhibited similar characteristics to commercial INUs. In the yogurt samples, the addition of INU resulted in a decrease in syneresis. Compared with the control samples, all the samples enriched with INU or INU-containing maltodextrin presented the highest viscosity values compared to the control. In the sensory evaluation conducted with 20 panelists, all yogurt of the samples were generally accepted. However, the samples enriched with globe artichoke root INU received slightly lower overall acceptance scores than the other samples did. All the samples were positively evaluated in terms of freshness, pleasant aroma, creamy texture, and overall flavor.

The form in which prebiotics and probiotics are integrated into yogurt is also important. For example, a study conducted in 2021 demonstrated that supplementing with microencapsulated synbiotics had greater lactic acid bacteria viability than yogurt supplemented with free synbiotics [131]. Also, it was demonstrated that the addition of encapsulated synbiotics enhanced the texture and rheological characteristics of the yogurt, thereby improving product quality [89].

In addition, it is possible to isolate prebiotics from various sources and evaluate these sources [29,76]. In this study, the effects of prebiotic sources, including *Malva neglecta* and lactulose, on the microbiological and textural characteristics of synbiotic yogurt developed with the probiotic bacterium *Limosilactobacillus fermentum* (*L. fermentum*) were evaluated [78]. The results demonstrated that the addition of 2% lactulose considerably increased the growth of starter bacteria, whereas the addition of 1% lactulose or 5%, 10%, or 15% *Malva neglecta* affected the growth of starter bacteria. In addition, the growth of *L. fermentum* was highest in the samples containing 2% lactulose and 15% *Malva neglecta*. According to the textural evaluation results, increasing the concentrations of lactulose and *Malva neglecta* significantly reduced the firmness of the yogurt. These results showed how different prebiotic sources affect the textural and functional properties of the product.

In a sense, synbiotic yogurt generally does not affect fat and protein content but does affect the rheological, sensory, and functional properties of yogurt. The addition of prebiotics to yogurt improved the survival and viability of the probiotics. This helps maintain the probiotic content of yogurt throughout its shelf life.

2.4. Fortified/Added Functional Ingredient

With the addition of various materials to yogurt, production can enhance the nutritional and functional properties [93,108]. These components can include plants, fruits, vegetables, grains, and dairy products or their bioactive contents [41,110]. These fortified materials can enhance the protein, carbohydrate, fat, vitamin, and mineral contents of the product [94]. In addition, they can also affect the physicochemical, textural, and sensory characteristics of the products [98,109,113].

Various fruits, vegetables, and grains are among the most common fortified foods added to yogurt [115,118]. The study by Vahdat et al. aimed to demonstrate the physicochemical properties of yogurt samples with different probiotic bacterial combinations and leek addition [99]. The results revealed that increasing the lipid content generally led to increases in the antioxidant capacity and acidity. However, this addition also affected the yogurt texture. In some samples, the use of various probiotics influenced acidity and probiotic viability. Some combinations increased antioxidant activity, whereas others improved digestibility and stability. The inclusion of the leek also enhanced the texture of this group. While probiotics partially balanced these effects, overall negative impacts on stability, digestibility, and antioxidant capacity were observed.

Fruits, pure fruit, seed, peel, pulp, and flour are also used as ingredients in the production of functional yogurt [40,95,103,117]. A recent study investigated the effects of adding banana pulp to yogurt produced with *Levilactobacillus brevis* on the physicochemical, textural, and sensory properties of the product [100]. With the addition of banana pulp, the moisture content decreased, whereas the percentage of dry matter increased. The water-holding capacity significantly increased, and the degree of syneresis decreased. The samples containing unripe banana pulp had greater preferences after 15 days of cold storage.

Substances classified as nutraceuticals can also be added to yogurt [96,102]. In a study investigating the effects of adding microencapsulated vitamin D to yogurt [101], the results demonstrated that the flavor score of yogurts supplemented with vitamin D was greater than that of the control yogurt, although the difference was not statistically significant. When the textures of the yogurts were compared, the yogurt with vitamin D received higher scores. In terms of overall acceptability, yogurt supplemented with added vitamin D was found to be more favorable by participants.

Another study aimed to investigate the effects of various components known to potentially improve the gut microbiota and intestinal barrier functions when added to yogurt [132]. Commercially available powders of L-glutamine, quercetin, slippery elm bark, marshmallow root, N-acetyl-D-glucosamine (NAG), licorice root, maitake mushroom, and zinc orotate were incorporated into yogurt. It is hypothesized that the addition of these components to yogurt could reduce intestinal issues and provide benefits. According to the pH results, the addition of L-glutamine significantly increased pH values, whereas quercetin, slippery elm bark, marshmallow root, NAG, zinc orotate, maitake mushroom, and licorice root did not affect the yogurt's pH values. The titration acidity (TA) results revealed that yogurt samples containing L-glutamine and NAG had significantly lower TA values than the control yogurt, whereas the other components generally presented similar TA values. In terms of syneresis, yogurt samples containing slippery elm bark exhibited less syneresis compared to a control yogurt, while other components did not show significant differences. Similarly, the viscosity results showed that marshmallow root, L-glutamine, NAG, slippery elm bark, zinc orotate, licorice root, and quercetin did not exhibit a significantly different viscosity compared to control samples, whereas maitake mushroom samples showed significantly lower viscosity. The sensory properties and consumer responses of yogurt samples were evaluated, revealing that yogurt samples

containing L-glutamine and marshmallow roots generally scored significantly lower than the control samples did. Overall, the added components were found not to significantly alter the physicochemical properties of yogurt. In conclusion, this study successfully aimed to identify alternative products for individuals experiencing gut health issues.

Additionally, animal products can also be included in the production of functional yogurt [107]. For example, bee pollen is a natural food containing various beneficial components, including proteins, carbohydrates, vitamins, and minerals, and is associated with many potential health benefits, including antioxidant, immunomodulatory, anti-inflammatory, cardioprotective, and hepatoprotective effects. This study evaluated the antimicrobial properties of probiotic yogurt containing different proportions of bee pollen [107]. In the disk diffusion tests, the control group showed no inhibitory effects on any pathogens, but the sample containing 6% bee pollen inhibited against *Salmonella typhimurium*, *E. coli*, and *Staphylococcus aureus*. The results demonstrated that bee pollen has beneficial effects on antimicrobial properties and probiotic viability and can, therefore, be considered an innovative approach. This study emphasizes the potential use of bee pollen as a component to improve the functional properties of probiotic yogurt.

The rich content of milk and dairy products, along with their derived components, are enriched during the production of functional yogurt, thereby increasing the quality of the product [114,133,134]. The first milk produced by mammals, colostrum has a richer composition than regular milk [135]. For example, a recent study revealed that integrating colostrum into yogurt increased the fat and protein contents [136]. Although the sample had high sensory acceptability, it was lower than that of the control sample. Lactoferrin, another antimicrobial bioactive substance found in milk, has multifunctional properties [137,138]. These properties led to the development of lactoferrin as an active ingredient in yogurt, which can be isolated from milk or colostrum [139]. A recent study demonstrated that the fortification of yogurt with lactoferrin increased its protein and dry matter contents [116]. It enhanced the sensory and physical properties of yogurt, improving its quality during storage.

Additionally, adding food waste and byproducts to yogurt production enhances the nutritional profile of the yogurt while allowing for the valorization of these materials [50,140]. In a study conducted by Sharifi, the effects of adding carrot waste extract to yogurt on its physicochemical, antioxidant, and sensory properties were evaluated [111]. Additionally, the impact of different encapsulation methods of *L. plantarum* probiotic bacteria on this composition was investigated. When the survival rate of *L. plantarum* during storage was examined, the highest survival rate was observed for yogurt containing carrot extract and a sodium alginate coating. This difference is thought to be due to the phenolic components of the carrot extract and the potential prebiotic content of *A. homolocarpum* seed gum. With respect to pH evaluation, all samples experienced a decrease in pH during storage, with samples containing carrot extract demonstrating higher pH values than the other samples did. Similarly, samples containing carrot extract exhibited lower acidity and less syneresis than the other samples did. Additionally, a higher water-holding capacity was observed in samples containing carrot extract. When the total polyphenol content and DPPH radical-scavenging activity were evaluated, it was determined that the fifth sample (probiotics coated with sodium alginate and *A. homolocarpum* seed gum containing carrot extract) increased the phenolic content and enhanced the DPPH radical-scavenging activity. Samples with added carrot extract were noted for better color and appearance. Furthermore, samples containing encapsulated probiotics received higher scores than those with free bacteria. Similarly, samples with added carrot extract received higher scores for texture and consistency. Overall, the acceptance results indicated that the microencapsulated samples scored higher than the samples containing free bacteria, with the highest score belonging to the fifth sample (yogurt coated with sodium alginate and *A. homolocarpum* seed gum containing carrot extract), which was determined to have the highest quality.

Nanoparticles are used in food products, particularly to extend shelf life, enhance nutritional value, and improve sensory characteristics [141]. The development of polymer-

ized whey nanoparticles derived from whey, considered to be waste and a byproduct, can facilitate valorization. In a previous study, polymerized whey nanoparticles were added to yogurt to mitigate the bitter taste of *Panax notoginseng* saponins (PNS) and enhance their nutritional value [94]. The effects on the rheological and textural properties of yogurt were investigated. The results showed that increasing the nanoparticle concentration was correlated with enhanced gelation kinetics, contributing to a stronger gel structure during fermentation. Additionally, a texture evaluation indicated that samples with higher nanoparticle contents presented higher hardness, elasticity, and adhesiveness but lower syneresis. The pH values were similar across all samples. Electronic tongue measurements demonstrated a significant reduction in yogurt bitterness with the addition of these nanoparticles. In a research study, yogurt was fortified with a nanocasein and pectin complex [97]. It was determined that the protein content and total dry matter amount of functional yogurt enriched with nano-casein and pectin complex increased, while viscosity increased and syneresis decreased. It was determined that this situation was due to casein micelle stability and the hydrophilic structure of pectin. It was emphasized that the LAB content of the enriched yogurt samples was higher, and this was due to the prebiotic effects of pectin. Similarly, when yogurt samples prepared with the addition of nanoliposomes containing bitter melon extract were examined, the syneresis was determined to be less and the viscosity was higher than in the control samples [104]. This situation is explained by the ability of liposomes to bind water in the yogurt matrix better or to prevent water loss. In general, when the studies are evaluated, it is revealed that nanoparticles improve the quality of the product in functional yogurt production [105].

In summary, the addition of bioactive components to yogurt production from fruits, vegetables, grains, and dairy products enhances the quality and nutritional, as well as the functional, properties of the product. The properties of the added component improved both the fermentation process and the content of the product after fermentation. Depending on the added compound, the total phenolic content may increase, and the antioxidant activity may improve due to its radical-scavenging activity. Importantly, optimizing the transportability of the added component within the yogurt matrix and its overall impact on product quality and general acceptability are crucial points that need to be addressed.

2.5. Others

In addition to probiotic, prebiotic, symbiotic, and fortified functional yogurt products, there are various other types of functional yogurt. These include high-protein and lactose-free yogurts [124].

2.5.1. High Protein

High-protein yogurt is a type of functional yogurt preferred by athletes, among others. These products are produced by adding proteins obtained from different protein sources to yogurt. In one study, four different samples were prepared, namely control yogurt, yogurt supplemented with *Lactobacillus helveticus* (*L. helveticus*), high-protein yogurt, and high-protein yogurt supplemented with *L. helveticus* [112]. The aim was to analyze the physicochemical properties and peptide profiles of these samples. When the effect on fermentation was evaluated, the addition of *L. helveticus* shortened the duration of fermentation regardless of protein content. The improvement in protein content significantly affected this process. The samples with added *L. helveticus* had lower pH values, resulting in higher titration values. Compared with the other samples, high protein samples presented greater total solid contents. The total number of lactic acid bacteria was within standard limits for all the yogurt samples, with the highest value observed in the yogurt sample with added *L. helveticus*. The peptide profiles of the yogurt samples were analyzed. According to the analysis results, peptides with potential ACE inhibitory activity were more abundant in yogurt samples with added *L. helveticus*. A significant increase in ACE inhibitory activity was observed in yogurt supplemented with *L. helveticus*. However, this effect was not detected in high-protein yogurt.

2.5.2. Lactose Free

Lactose, which is composed of glucose and galactose, is found in high amounts in milk and dairy products. It has been identified as the main source of problems experienced after the consumption of milk and dairy products. The number of individuals experiencing indigestion, nausea, and discomfort after consuming milk and dairy products has rapidly increased in the last 10 years [123]. These problems prevent individuals from consuming milk and dairy products, depriving them of the health benefits these products bring. Currently, various lactose-free food products are being produced. There is also a lactose-free option available for yogurt products. This functional product not only provides the benefits but also minimizes the problems that can arise from lactose for lactose-intolerant individuals [122].

β -galactosidase is an enzyme derived from fungi that is widely used in dairy products to hydrolyze lactose [121]. A recent study investigated the potential use of whey powder for producing lactose-free yogurt without added sugars [120]. Considering that the addition of whey powder increases the lactose content, lactose was hydrolyzed into glucose and galactose using the β -galactosidase enzyme. These monosaccharides, which are sweeter than lactose, make whey powder a suitable alternative to sugar. This study involved incorporating the β -galactosidase enzyme from *Aspergillus oryzae* into yogurt containing different concentrations of whey powder, resulting in a considerable reduction in lactose content postfermentation compared with that of the control sample. A sensory evaluation indicated that samples with whey powder contents ranging from 0% to 10% presented an increased milky taste and creaminess. Additionally, an increase in whey powder content was associated with a more yellowish color of the samples. These products were found to have higher protein and fat contents than the control sample. The texture parameters revealed that the lactose-free samples maintained a firmer structure during storage. There was no significant difference in the water-holding capacities between the lactose-free samples and the control sample, but overall quality improvements were observed in the lactose-free samples.

A study aimed at producing lactose-free probiotic yogurt utilizing *Bifidobacterium animalis* ssp. *lactis* (*B. animalis* ssp. *lactis*) in both free and microencapsulated forms [37]. During storage, the survival rates of the probiotics in all of the samples were in accordance with the standards. The pH values of all samples decreased throughout storage, with the lowest pH observed in the sample containing free probiotics. The sample with INU presented an improved texture and reduced syneresis, whereas the sample with free probiotics showed increased syneresis. In conclusion, microencapsulation and appropriate storage conditions were found to influence the survival rate of probiotics and the physical and textural properties of yogurt.

2.5.3. Easy to Digest

In addition to these products, the production of yogurt made from A2 milk, which has easy digestibility properties, is an innovative approach [142,143]. A point mutation results in the formation of A1 milk [144,145]. These two types of milk lead to the formation of different metabolites after digestion. At this point, studies have evaluated symptoms following the consumption of A2 and A1 milk in individuals with lactose intolerance and normal individuals and reported that intolerance symptoms are reduced with A2 milk consumption [8]. There is a need for further research in the field of A2 yogurt [38,146].

Overall, studies demonstrate that there are innovative approaches to the production of functional yogurt (Figure 1). These added materials significantly affect the nutritional, sensory, and functional properties of yogurt.

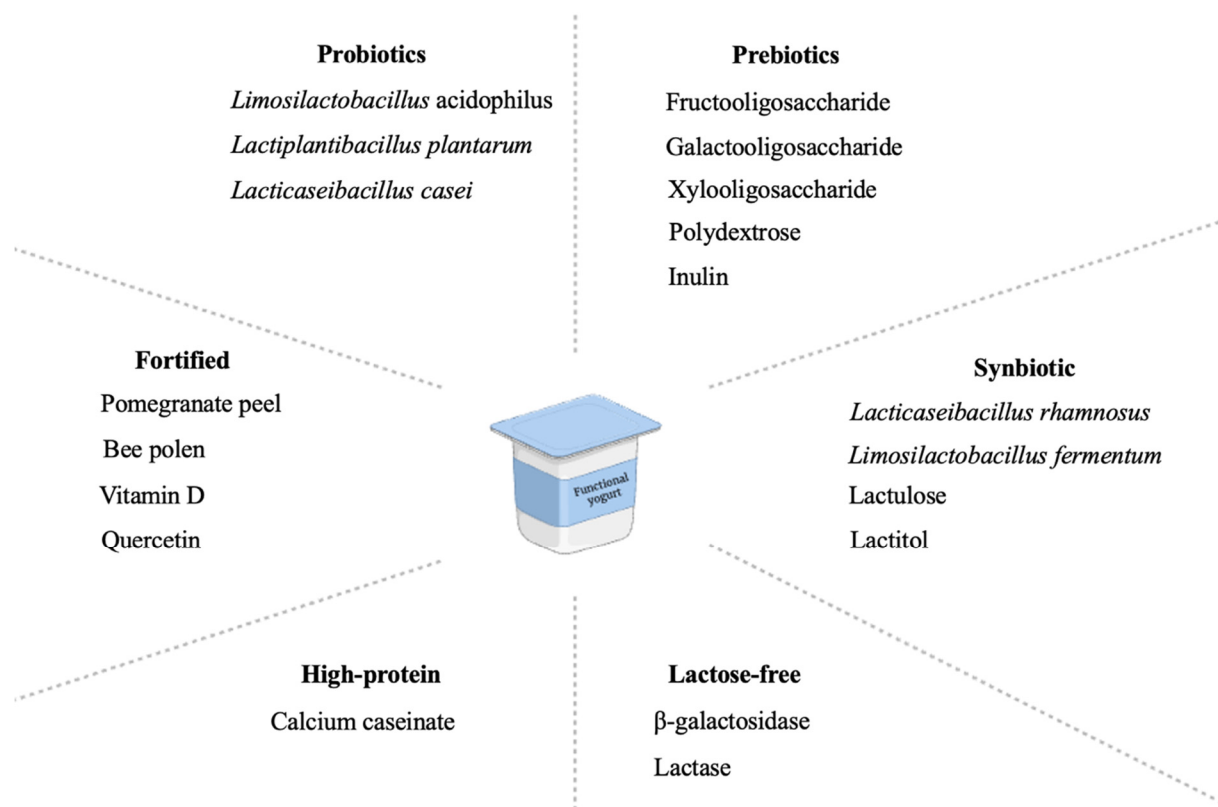


Figure 1. Functional yogurt varieties.

3. Health Benefits Associated

The health effects of yogurt consumption have been examined from many perspectives. These effects include the prevention of diseases or altering the course of diseases through yogurt consumption (Table 2) [30]. As a result of the consumption of functional yogurt, it is possible to modulate biochemical indicators, thereby exhibiting health-promoting functions [147,148].

Table 2. Health benefits associated with yogurt consumption.

Function Related	Type of Functional Yogurt	Added Component	Outcomes	References
Digestive health	Probiotic yogurt	Tumbo fruit (<i>Passiflora tripartita</i> Kunth)	- Exhibit antioxidant capacity - Enhance product quality	[46]
	Synbiotic yogurt	Purple-leaf tea (<i>Camellia sinensis</i>)	- Modulate gut microbiota	[149]
	Probiotic yogurt	*	- Reduce frequency and severity of vomiting and diarrhea	[30]
	Synbiotic yogurt	<i>Bifidobacterium</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> Inulin Maitake mushrooms Quercetin L-glutamine	- Modulate gut microbiota - Modulate lipid metabolism	[147]
	Fortified yogurt	Slippery elm bark Licorice root N-acetyl-D-glucosamine Zinc orotate Marshmallow root	- Exhibit antioxidant activity - Enhance intestinal barrier function	[6]
	Probiotic yogurt	*	- Modulate gut microbiota	[34] (Chai et al., 2023)
	Yogurt	*	- Modulate gut microbiota	[150]

Table 2. Cont.

Function Related	Type of Functional Yogurt	Added Component	Outcomes	References
Digestive health	Fortified yogurt	Isabel grape	- Modulate gut microbiota	[33]
	Probiotic yogurt	<i>Bacillus amyloliquefaciens</i>	- Exhibit immunomodulatory effects	[151]
	Yogurt	*	- Alleviate the colitis symptoms	[125]
	Probiotic yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- Modulate gut microbiota	[49]
		<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Improve metabolic parameters	
	Fortified yogurt	Vitamins		
		<i>Lactocaseibacillus casei</i>	- Exhibit immune effects	[152]
		<i>Lactocaseibacillus rhamnosus</i>		
	Fortified yogurt	Orange juice	- Modulate gut microbiota	[148]
		<i>Bacillus coagulans</i>	- Improve biochemical parameters	
	Probiotic yogurt	<i>Bifidobacterium</i> spp.	- Modulate gut microbiota	[153]
		<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- Modulate gut microbiota	
	Probiotic yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Enhance intestinal barrier function	[126]
	Probiotic yogurt	*	- Modulate diarrhea associated with antibiotic use	[154]
	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i>	- Modulate diarrhea symptoms	[155]
		<i>Bifidobacterium bifidum</i>		
		<i>Limosilactobacillus acidophilus</i>		
		<i>Lactiplantibacillus plantarum</i>		
Cardiovascular health		<i>Lactocaseibacillus paracasei</i>		
		<i>Bifidobacterium animalis</i> subsp. <i>lactis</i>		
		<i>Bifidobacterium longum</i>	- Modulate gut microbiota	
		<i>Bifidobacterium breve</i>	- Modulate constipation symptoms	[156]
	Synbiotic yogurt	Fructooligosaccharides		
		Inulin		
		Polydextrose		
		Galactooligosaccharides		
		Isomaltoligosaccharides		
		Xylooligosaccharides		
	Synbiotic yogurt	Konjac mannan oligosaccharides	- Modulate gut microbiota	[83]
		<i>Bifidobacterium animalis</i> ssp. <i>lactis</i>		
		<i>Lactiplantibacillus plantarum</i>	- Modulate gut microbiota	
	Probiotic yogurt	<i>Lactobacillus casei</i> subsp. <i>casei</i>	- Modulate constipation symptoms	[157]
		<i>Lactococcus lactis</i> subsp. <i>lactis</i>		
	Probiotic yogurt	<i>Bifidobacterium</i> sp.	- Reduce lactose intolerance symptoms	[54]
		<i>Limosilactobacillus acidophilus</i>		
	Yogurt	*	- Modulate constipation symptoms	[158]
	Yogurt	Lactoferrin	- Reduce gastroenteritis symptoms	[139]
	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i>	- Enhance blood lipid profiles	[159]
		<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>		
	Fortified yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Enhance nutritional value	[7]
		<i>Bacillus subtilis</i>	- Exhibit antioxidant capacity	
		Lycopene	- Enhance the bioactive content	
	Probiotic yogurt	*	- Enhance blood lipid profiles	[28]
			- Exhibit anti-inflammatory activity	
	Fortified yogurt	Olive oil byproducts	- Exhibit antithrombotic activity	[45]
	Yogurt	*	- Regulate heart rate	[160]
	Fortified yogurt	Omega fatty acids	- Regulate systolic and diastolic blood pressure	[161]
		Flaxseed powder		

Table 2. Cont.

Function Related	Type of Functional Yogurt	Added Component	Outcomes	References
Cardiovascular health	Probiotic yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Modulate gut microbiota - Exhibit antihypertensive effects - Enhance blood lipid profiles	[162]
	Yogurt	*	- Enhance blood lipid profiles	[163]
	Yogurt	*	- Enhance blood lipid profiles	[164]
	Yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Exhibit anti-hypertensive effects	[165]
	Probiotic yogurt	*	- Modulate oxidative stress - Exhibit antioxidant activity	[166]
	Yogurt	*	- Modulate plasma concentration	[39]
Metabolic health	Probiotic yogurt	<i>Lactiplantibacillus plantarum</i> <i>Lactocaseibacillus rhamnosus</i>	- Exhibit antioxidant effects - Modulate oxidative stress markers	[167]
	Probiotic yogurt	*	- Modulate gut microbiota - Modulate oxidative stress markers - Modulate lipid metabolism	[168]
	Probiotic yogurt	<i>Limosilactobacillus fermentum</i>	- Modulate gut microbiota - Improve biochemical serum parameters	[43]
	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- Improve insulin sensitivity	[169]
	Fortified yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Limosilactobacillus acidophilus</i> Vitamin D	- Modulate gut hormones	[170]
	Probiotic yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Limosilactobacillus acidophilus</i> Yacon flour	- Improve inflammatory markers - Improve insulin sensitivity	[171]
	Probiotic yogurt	<i>Lactiplantibacillus plantarum</i> <i>Bacillus subtilis</i> variant <i>natto</i> Soybean flour	- Modulate blood lipid parameters - Assist with weight loss	[172]
	Fortified yogurt	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> Vitamin D	- Enhance blood lipid profiles	[173]
	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i>	- Improve anthropometric parameters - Enhance blood lipid profiles	[174]
	Synbiotic yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Lactococcus lactis</i> subsp. <i>cremoris</i> Yellow sweet potato	- Assist with weight loss	[175]
	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i>	- Enhance blood lipid profiles - Improve anthropometric parameters	[42]
	Yogurt	*	- Improve immune markers	[176]
	Yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Improve immune markers	[177]
	Synbiotic yogurt	<i>Limosilactobacillus acidophilus</i> Konjac mannanoligosaccharide <i>Limosilactobacillus acidophilus</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- Modulate gut microbiota - Exhibit immunomodulatory effects	[178]
Immune health	Fortified yogurt	<i>Bifidobacterium longum</i> Ginseng	- Exhibit antioxidant effects	[179]

Table 2. Cont.

Function Related	Type of Functional Yogurt	Added Component		Outcomes	References
Oral health	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Bifidobacterium longum</i> <i>Salvadora persica</i>	-	Reduce the demineralization of enamel	[180]
	Probiotic yogurt	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Streptococcus mutans</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	-	Modify the oral biofilm	[181]
	Probiotic yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Limosilactobacillus acidophilus</i> <i>Lactocaseibacillus casei</i>	-	Modulate oral microbiota	[182]
	Probiotic yogurt	<i>Limosilactobacillus fermentum</i>	-	Exhibit antibacterial and anticavity activities	[183]
Antioxidant activity	Fortified yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Lactococcus lactis</i> subsp. <i>lactis</i> <i>Psidium cattleianum</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	-	Modulate phenolic compounds level	[184]
	Fortified yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> Soy whey-derived peptide <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- - -	Enhance the bioactive content Exhibit antibacterial function	[44]
	Synbiotic yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Lactocaseibacillus rhamnosus</i> Soybean waste <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- - -	Exhibit radical scavenge activity Enhance phenolic contents	[140]
	Synbiotic yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Saccharomyces boulardii</i> Inulin	- - -	Exhibit radical scavenge activity Enhance phenolic contents	[185]
	Fortified yogurt	<i>Escherichia coli</i> Nissle <i>Physalis peruviana</i>	- -	Enhance phenolic contents Exhibit antimicrobial activity	[186]
	Probiotic yogurt	<i>Lactiplantibacillus plantarum</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Limosilactobacillus acidophilus</i> <i>Lactocaseibacillus casei</i> <i>Bifidobacterium bifidum</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- - - - - -	Exhibit anti-glycemic activity Maintain HbA1c levels	[187]
Anti-diabetic activity	Fortified yogurt	<i>Lactocaseibacillus rhamnosus</i> <i>Bifidobacterium longum</i> subsp. <i>infantis</i> <i>Bifidobacterium longum</i> <i>Illicium verum</i> <i>Psidium guajava</i> <i>Codonopsis pilosula</i> <i>Lycium barbarum</i> <i>Cinnamomum verum</i> and <i>Stevia rebaudiana</i> Corinthian and Sultana raisins Red guava extract	- - - - - - - - -	Enhance phenolic contents Exhibit radical scavenge activity Exhibit α -amylase and α -glucosidase inhibitory activity	[188–190]
	Probiotic yogurt	<i>Limosilactobacillus acidophilus</i> <i>Bifidobacterium animalis</i> subsp. <i>lactis</i> <i>Streptococcus salivarius</i> subsp. <i>thermophilus</i>	- - -	Exhibit anti-glycemic activity Maintain HbA1c levels	[191]
	Synbiotic yogurt	<i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i> <i>Limosilactobacillus acidophilus</i> Monk fruit extract	- - -	Modulate liver biomarkers	[192]

Table 2. Cont.

Function Related	Type of Functional Yogurt	Added Component	Outcomes	References
Anticancer activity	Yogurt	<i>Streptococcus salivarius</i> subsp. <i>thermophilus</i> <i>Lactobacillus delbrueckii</i> subsp. <i>bulgaricus</i>	- Exhibit chemopreventive activity	[193]
	Yogurt	*	- Reduce number of tumors	[194]
	Yogurt	*	- Reduce colorectal cancer risk	[195]

* Not identified.

3.1. Digestive Health

From this perspective, the effects of functional yogurt consumption on the digestive system, and particularly gut health, have been investigated in various aspects [33,126]. The digestive system, also referred to as the gastrointestinal system, creates a network that affects all systems from the mouth to the anus [196]. This network is composed of a structure covered with mucus formed by epithelial cells, immune cells, and tissues. This structure is considered a habitat for microorganisms. The gut microbiota has an important impact on human health and diseases [196].

Notably, functional yogurt consumption promotes the development and regulation of the gut microbiota [34,49]. Probiotic, prebiotic, and synbiotic yogurt are commonly consumed products for the treatment of gastrointestinal disorders, including malabsorption, diarrhea, and constipation [153,157]. In addition, yogurt consumption is prevalent after conditions that cause damage to the gut microbiota, such as antibiotic use [150,154]. Additionally, fortified or added functional yogurt material can also play a role in regulating and developing the gut microbiome [125]. Depending on the added material, this type of functional yogurt has been found to improve gut barrier function as well [6,158].

In this context, various studies have been conducted using experimental animals, such as mice, rats, and rabbits, to evaluate the toxicity and safety of functional yogurt samples [149,151]. Following physicochemical and microbiological tests of probiotic yogurt prepared from Tumbo fruit (*Passiflora tripartita* Kunth), preclinical studies of this yogurt have been carried out [46]. Throughout the study, the conditions of the rats were controlled by various parameters, including hematological and biochemical parameters, and this test was carried out to determine the toxicity and safety of probiotic yogurt. During this observation process, the liver and kidneys were examined macroscopically, and no differences in color, surface area, and consistency were found between the control and experimental groups. However, the average body weight of the experimental animals increased to the normal level after 14 days, and no major difference was detected when the control and experimental groups were compared. When hematological and biochemical serum parameters were evaluated, hemocrit, hemoglobin, red blood cells, platelets, neutrophils, and other parameters were significantly different between the control and experimental groups. This was attributed to an improvement in immune status as a result of nutrition. Moreover, biochemical serum parameters demonstrated that, compared with the control group, the experimental group had better liver function. The experimental group presented lower values of glucose, cholesterol, and triglyceride. These results reveal that when nutrition is supported with probiotic yogurt, yogurt may exhibit health-promoting properties.

In addition, diarrhea can cause the loss of fluids, minerals, and sugars from the body, contingent upon the severity and duration of the condition [155]. Probiotics and prebiotics are mainly used to modulate intestinal motility in the treatment of diarrhea. Similarly, yogurt consumption is prevalent for modulating infrequent bowel movements and intestinal motility in cases of constipation [83,156]. In a recent comprehensive study conducted by Li et al., the effects of synbiotic yogurt on the intestinal microbiome and gastrointestinal symptoms, particularly in relation to constipation, were investigated [156]. *L. delbrueckii* subsp. *bulgaricus* and *S. salivarius* subsp. *thermophilus* containing a starter culture were used to ferment the milk and probiotic bacteria, and *Limosilactobacillus acidophilus*, *L. plantarum*,

Lactobacillus paracasei, *Bifidobacterium animalis* subsp. *lactis*, *Bifidobacterium longum*, and *Bifidobacterium breve* were added. To produce synbiotic yogurt, prebiotics including FOS, INU, PDX, GOS, isomaltooligosaccharides, and XOS were also included. The results demonstrated improvements in stool frequency, stool water content, and intestinal transit rate. In antibiotic-induced constipation, yogurt consumption triggers increased stool quantity and stool water content and enhances intestinal motility. Additionally, yogurt can modulate the gut microbiota. The effects of yogurt consumption on constipation symptoms were clinically investigated over a 4-week period in 86 individuals with constipation. During this period, the safety of yogurt containing both probiotics and prebiotics was confirmed, and the alleviation of constipation symptoms was observed. However, no considerable differences were found in the gut microbiome before and after treatment. Owing to its high oligosaccharide content, milk can serve as a food source for probiotic bacteria, thereby functioning as a prebiotic [197–199]. Similarly, in a study conducted in 2021, in the production of synbiotic yogurt, konjac mannan oligosaccharides were used as prebiotics. These compounds contributed to the growth of the probiotic bacterium *B. animalis* ssp. *lactis* and played a role in the regulation of the gut microbiota [83]. Overall, the consumption of synbiotic yogurt enhanced defecation function, gut functions, and the repair of intestinal damage in relation to constipation.

3.2. Cardiovascular Health

Cardiovascular diseases, which are directly related to the commonly encountered dietary patterns today, directly affect heart health [159]. The most well-known factors causing heart diseases are alterations in blood lipid content and blood pressure indices [45]. The effects of yogurt consumption on cardiometabolic parameters are being investigated [45,162,165]. Studies have shown that functional yogurt products promote health by increasing oxidative stress parameters and exhibiting antioxidant properties [166].

One study aimed to evaluate the effects of yogurt enriched with extruded flaxseed powder on the serum lipid profile and blood pressure indices of hypercholesterolemic individuals [161]. The total dietary fiber and raw fat contents of extruded flaxseed powder-fortified yogurt increased substantially. An analysis of the results from the first group revealed considerable increases in total cholesterol and low-density lipoprotein (LDL) cholesterol levels in participants who consumed plain sheep milk yogurt. However, a significant reduction in these values was observed in participants who consumed fortified sheep milk yogurt. On the other hand, no major change was observed in the values of participants consuming plain cow yogurt in the second group. The participants who consumed fortified cow yogurt presented improvements in blood pressure indices. Another study examining yogurt consumption and changes in blood pressure indices reported that participants with high yogurt consumption had lower blood pressure, triglycerides, and fasting glucose values [163]. Additionally, regular yogurt consumption is also related to potential beneficial effects on heart rate [160].

3.3. Metabolic Health

Metabolic diseases refer to conditions that arise from disturbances in the body's processes of energy consumption, storage, and utilization [173]. These are especially considered risk factors for kidney diseases and cardiovascular diseases, such as type 2 diabetes, hypertension, and insulin resistance [43,167,171]. In particular, an increase in oxidative stress in obese individuals can result in a decrease in antioxidant defenses, which may cause the onset of various diseases [171,172]. The effects of probiotic yogurt consumption on the unhealthy gut microbiome in obese individuals have been investigated in different studies [170,171]. A study by Rezazadeh et al. showed significant changes in glycemic parameters after probiotic yogurt consumption by participants [169]. Considerable reductions in serum uric acid and insulin levels were observed. Additionally, the probiotic yogurt consumption, combined with a low-calorie diet, improved lipid profiles and body weight [174,175].

A previous study by Zhu et al. investigated the effects of probiotic yogurt consumption on metabolic-associated fatty liver disease (MAFLD), which is linked to metabolic health issues [168]. The study evaluated the impact of probiotic yogurt consumption in participants on a high-fat diet. After 8 weeks of probiotic yogurt consumption, significant reductions in plasma triglycerides, total cholesterol, and LDL levels were observed. Additionally, the consumption of probiotic yogurt remarkably reduced liver damage and oxidative stress caused by the high-fat diet. These results suggest that probiotic yogurt could be effective in mitigating the adverse effects of a high-fat diet and supporting liver health.

3.4. Immune Health

The immune system can be affected by diet to regulate immune markers to prevent the onset of chronic diseases in healthy individuals. Consequently, dietary additions are estimated to alleviate chronic inflammation and exhibit immunomodulatory effects [178]. Research has focused on how the main elements of the immune system, including immunoglobulins and other immunological components, are modulated by the consumption of foods. Within this framework, functional yogurt is regarded as a promising food that could play a crucial role in both the prevention and treatment of chronic diseases [176].

A recent study evaluated the impact of yogurt consumption on the immune system in healthy adults over an 8-week period [176]. The study included three types of yogurts, namely pasteurized, fresh, and sterilized. The findings revealed variations in leukocyte and lymphocyte counts based on the type of yogurt consumed. Additionally, yogurt consumption influences immunoglobulin levels, cytokine levels, and natural killer (NK) cell activity, depending on the yogurt type. Another study revealed that probiotic yogurt prepared with added ginseng not only exhibited antioxidant properties but also affected the expression of immunomodulatory factors [179]. Moreover, a study involving 20 participants indicated that consuming yogurt at 340 g/day for 4 weeks could alleviate systemic inflammation [177].

3.5. Oral Health

Nutrition is one of the factors that directly affect oral and dental health. Dental issues, such as lifespan, are considered among the most common problems [180]. Dental caries is a process that starts with demineralization of the enamel and continues through other layers, caused by changes in the oral microbiota [182]. Addressing this issue is crucial, as it may help reduce cavities and plaque, and consequently, indirect dental carries [180,183]. In a recent study conducted by Javid et al., probiotic yogurt consumption considerably reduced the amount of *Streptococcus mutans*, one of the main microorganisms responsible for tooth decay [181].

3.6. Other Effects

In addition, yogurt consumption is associated with several effects, including providing antioxidant, antidiabetic, and anticancer properties.

3.6.1. Antioxidant Activity

Conscious consumers are increasingly demanding the safe integration of antioxidant compounds into food products within the food industry [186]. Antioxidant activity helps mitigate oxidative stress, thereby preventing the development of various diseases and supporting disease management [185]. From this perspective, the use of antioxidant-rich components, primarily derived from plants and plant extracts, has been initiated in the production of functional yogurt. For example, a recent study investigated the antioxidant activity of functional yogurt enriched with *Psidium cattleianum* probiotics [184]. During the in vitro digestion process, phenolic compounds, such as ellagic and hydroxybenzoic acids, exhibited resistance. However, some compounds degrade during digestion, leading to the formation of new compounds. Although there was a reduction in antioxidant activity after digestion, α -glucosidase inhibition increased postdigestion. Another study conducted by

Mashayekh et al. explored the effects of adding soy whey peptides to yogurt on quality and shelf life [44]. Reverse-phase high-performance liquid chromatography chromatograms are used to analyze peptide fractions isolated from soy whey, which have high antioxidant and antibacterial properties. The DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging test revealed that peptide addition led to an increase in the DPPH scavenging percentage of yogurt samples during storage, indicating an increase in antioxidant activity over time.

Waste and byproduct materials can also contain bioactive compounds with antioxidant properties [140]. For instance, in a study conducted by Asghar et al., okara, a byproduct obtained from soybean processing, was used in the production of functional yogurt [140]. The results demonstrated that the utilization of okara provides an increase in total phenolic content, as well as enhanced DPPH radical scavenging and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical-scavenging activities. These findings are related to increased antioxidant properties.

3.6.2. Anti-Diabetic Activity

The prevalence of diabetes and prediabetes is rapidly increasing as a consequence of changing lifestyles, especially dietary habits. The prevalence of type 2 diabetes and prediabetes are the most well-known problems affecting lifespan [191]. In addition to the use of supplements and medications for the prevention and management of this disease, the consumption of functional foods is being promoted [192,200]. In this context, functional yogurt is considered a valuable food product. The glycated hemoglobin (HbA1c) level serves as a marker of glycemic control, allowing comparisons before and after the consumption of these products [187,191].

In a study conducted by Shori et. al, yogurt was produced by the fortification of medicinal plants with probiotic yogurt. The samples were examined for their phenolic content and α -amylase, and α -glucosidase inhibitory activities during storage [188]. In this study, *Psidium guajava* (leaves), *Lycium barbarum* (fruit), *Codonopsis pilosula* (roots), and *Illicium verum* (leaves) were utilized as plants known for their medicinal benefits. The results showed that yogurt containing *Lycium barbarum* contained a higher peptide concentration than the other yogurt samples did. Compared to the control sample, all the yogurt samples enriched with these plants presented greater total phenolic contents, radical-scavenging activities, and α -amylase and α -glucosidase inhibitory activities. These findings highlighted that fortified yogurt is a potential strategy for treating type 2 diabetes. Similarly, the protein content of cinnamon and stevia-added yogurts increased during storage [189]. However, the α -amylase inhibition of these products showed the highest inhibition value compared to others, with a 63% inhibition rate. It has been determined that the phenolic and bioactive compounds contained in cinnamon and stevia have anti-diabetic effects and reduce glucose absorption by suppressing α -amylase activity.

A trial conducted in 2022 aimed to investigate the postprandial blood glucose effects of goat milk yogurt with the addition of Corinthian raisins [190]. The results of the study showed that this product has a low glycemic index and glycemic load. In addition, it was concluded that it may contribute to glucose control by modulating postprandial blood sugar fluctuations.

3.6.3. Anticancer Activity

Over the past decade, the rate of cancer proliferation has reached an unstoppable level. As the disease progresses, researchers are exploring various alternatives to mitigate the risk of disease onset and support its treatment [194,195]. A study investigating the effects of yogurt consumption on colorectal cancer reported a lower tumor burden in mice supplemented with yogurt [193]. Additionally, yogurt supplementation reduces colitis severity and promotes improvements in colon length.

Yogurt consumption is associated with the development and modulation of various health aspects, including the digestive system, metabolic function, cardiovascular health, the immune system, and oral health (Figure 2). Additionally, it has been found to support

the preservation of kidney and liver functions. Moreover, yogurt has antioxidant, anti-inflammatory, antidiabetic, and anticancer effects, which contribute to these benefits for consumers. Consequently, functional yogurt has been identified as a food that can help prevent the onset and progression of diseases.

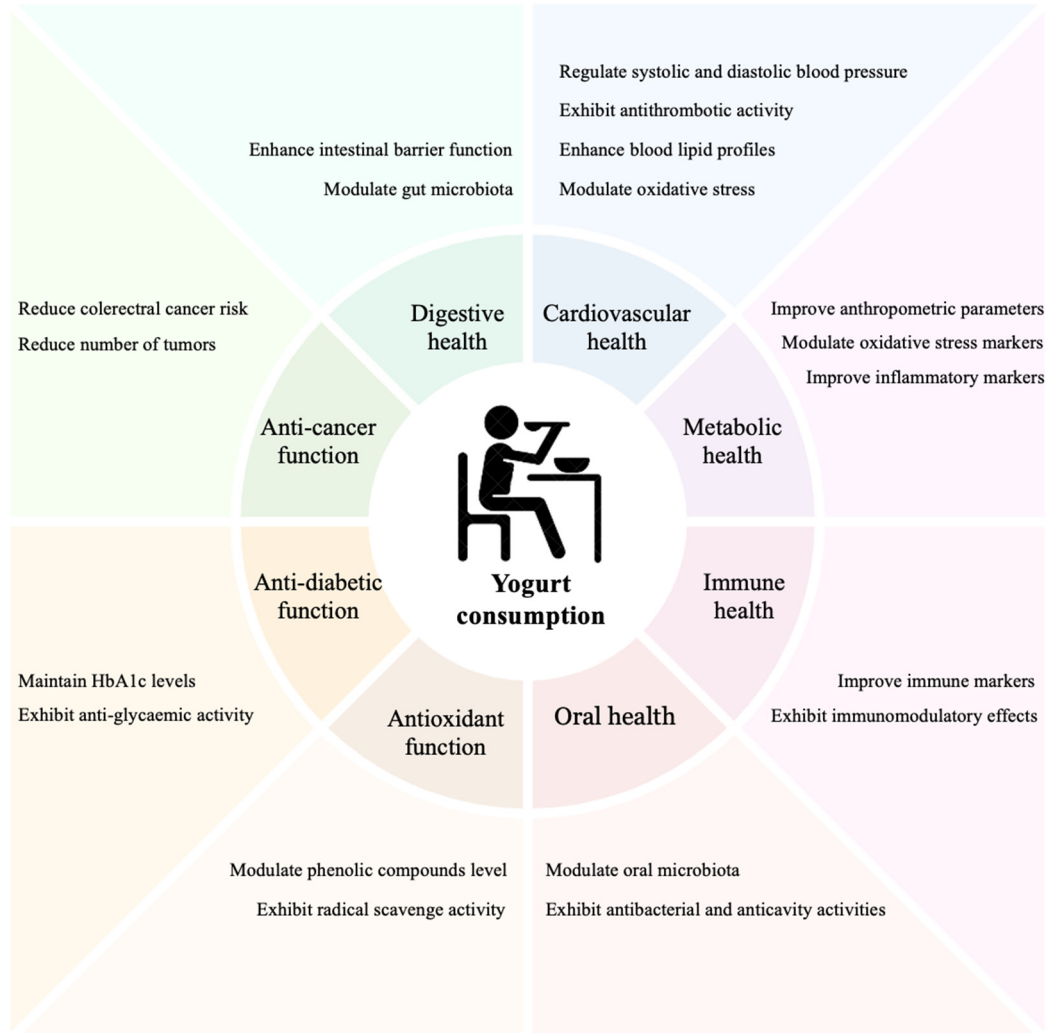


Figure 2. Health effects associated with yogurt consumption.

4. Conclusions

With increasing consumer awareness, the food industry has shifted its focus toward incorporating functional components into foods and developing healthy alternative products. In this context, the increasing interest in fermented foods has highlighted the production of functionally enhanced fermented yogurt products through the addition of various components. In this context, probiotics, prebiotics, synbiotics, enriched yogurt, and lactose-free yogurt have been widely produced. Among the suitable foods for the transportation of probiotics within the food matrix, dairy products, particularly milk and dairy products, stand out. Various methods have been employed to increase the viability and stability of probiotics, with encapsulation being one such method. This technique not only ensures the stability and viability of the encapsulated probiotics within the product but also improves their survival rate in the digestive system until they reach the intestines postconsumption. Probiotic, prebiotic, and synbiotic yogurts are among the most commonly encountered functional yogurt products on the market and are especially preferred in the presence of any condition affecting the gut microbiota. Furthermore, the fortification of yogurt

with different components is a commonly used method to increase yogurt content. By incorporating foods known for their benefits into yogurts in various forms, they serve a nutraceutical function. Research has demonstrated how the effects of these added compounds on pH, acidity, syneresis, and water-holding capacity can support the preservation and enhancement of yogurt's structural properties.

Additionally, functional yogurt consumption has been found to offer various health benefits. Among its primary effects on the digestive system are improving bowel functions and modulating the gut microbiota to promote recovery. It has also been emphasized that functional yogurt consumption alleviates the symptoms associated with constipation. Additionally, effects on cardiovascular health, including the regulation of blood lipid profiles, antihypertensive activity, and antioxidant capacity have been noted. Furthermore, it can assist in maintaining and regulating metabolic parameters within normal ranges, particularly in obese individuals. By modulating the levels of immunoglobulins and cytokines, which are key factors in the immune system, functional yogurt can stimulate the immune system, thereby helping to prevent and support the treatment of diseases.

The enhancement of the quality of functional yogurt products, the extension of their shelf life, and the maintenance of quality throughout this process often involve the incorporation of various materials into yogurt. However, further research is needed to increase the prevalence of functional yogurt consumption and to ascertain yogurt's health-related properties.

Author Contributions: Conceptualization, S.S. and S.K.; writing—original draft preparation, S.S., S.K., A.d.C.M.P., J.M.M. and A.M.W.; writing—review and editing, S.S., A.d.C.M.P. and A.M.W.; visualization, S.S.; supervision, J.M.M. and S.K. All authors have read and agreed to the published version of the manuscript.

Funding: This article received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

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