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Review

Factors Affecting the Quality of Probiotic Plant-Based Frozen Desserts—The Authors' Own Experiments in the Context of the Literature

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Abstract: Recently, there has been worldwide growth in consumer nutrition awareness, which has resulted in a market-driven increase in the demand for "functional food", which, in addition to traditional nutrients, also contains ingredients with specific properties that have a beneficial effect on human health. One of the types of functional food is so-called "probiotic food", which includes, for example, frozen desserts. These products appear attractive to the consumer because of their sensory, nutritional and refreshing qualities. Due to progress in science, genetics, the acquisition of new sources of probiotic microorganisms and new plant varieties, the beneficial effects of the characteristic metabolites of the microbiome—so-called postbiotics—and also aspects of NGPs (Next Generation Probiotics), work is under way to optimize the technology used during the production of such products. At the same time, there is an observed market-based increase in the supply of new formulations based only on plant-origin materials with different technological modifications, including prebiotic enrichment, which allows for the production of a synbiotic product. Therefore, the objective of this study is a narrative review, in combination with the authors' own experiments, concerning the impact of various factors on functional, plant-origin frozen desserts, from the point of view of maintaining their quality.

Keywords: probiotics; functional food; frozen desserts; quality factors; probiotic food product development

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1. Introduction

A change in customer preferences and eating habits is expected to drive a considerable upswing in the frozen food market in Europe in the upcoming years. There is expected to be a significant increase in demand, which might increase the market size by an estimated USD 48.81 billion between 2022 and 2027 [1].

The term frozen desserts commonly covers all kinds of desserts that are meant to be eaten in a frozen condition, including ice cream, sherbets, sorbets, frozen yogurts and non-dairy frozen desserts. There are different possibilities for grouping and classifying these products. The most popular desserts are sorbets, which include all products that have an acidic pH and are mainly made of water, with or without fruit [2]. Alternatively, according to Goff and Hartel (2013) [3], sorbets are a kind of frozen desserts that are defined as products containing essentially water and sugar, with a fruit content of at least 25%. No fat substances should be added, and neither should any chemical agent that increases or accelerates the production process [2]. It is estimated that the global frozen dessert market will thrive at a compound annual growth rate of 5.4% from 2019 to 2025 to reach USD

135.00 billion by 2025. Key factors that are driving the market growth include first of all increasing health consciousness and also changes in consumer tastes, rising disposable income and the introduction of various products in the dessert segment (Market analysis report by Grand View Research, 2020) [4]. This trend is enhanced by functional frozen food with probiotics and the "clean label food" idea as well, which means the product is confirmed to be "organic", "natural" (i.e., following natural production method) and/or "free from" artificial ingredients/additives [5]. The consumer demand for natural and "clean label foods" continues to grow [6].

Probiotic microorganisms are defined as "live microorganisms that, when administered in adequate amounts, confer a health benefit on the host" [7]. This definition is inclusive of a broad range of microbes and applications, whilst capturing the essence of probiotics (microbial, viable and beneficial to health) Probiotic microorganisms can be introduced through the consumption of fermented foods, as fortified food products or as pharmaceuticals. The high number of bacteria in the final functional product after storage tests and during distribution offers an opportunity for the delivery of an appropriate number of microorganisms to the GI tract [7,8]. In addition to the presence of living cells, the importance of the dead cells of these bacteria and their metabolites is emphasized. Live LAB that are present in the product after the fermentation process produce so-called postbiotics that modify the health value of products. Currently, an important area of research in the field of biotechnology is the assessment of the safety of microorganisms with probiotic properties, which demonstrate documented and beneficial effects on human health and are used in the production of functional foods and supplements. Some of the positive benefits of intestinal bacterial cells on health include altering the composition of the gut microbiota, adhering to mucosa and epithelium, and modifying the immune system. The generation of novel probiotic strains with tailored metabolite production and immunomodulatory activity is made possible by genetic engineering advancements [9,10].

Postbiotics have several advantages when it comes to their technological application as functional food additives. These include their pure form availability, ease of manufacture and dose, stability during storage and the capacity to produce on an industrial scale. While live LAB can be handled in a regulated and controlled manner, their utilization is contingent upon the quantity and metabolic activity of the particular strain employed. Postbiotics can be used to produce functional foods on an industrial scale, although doing so still presents significant challenges. The safety of postbiotics and their effect on the end product's sensory qualities are significant issues surrounding their usage in the manufacturing of functional food. However, as various literature sources show, the specific impact of postbiotics on these quality determinants depends on the food matrix used [11–13].

So far, the market in probiotic and postbiotic foods has been dominated by dairy products. At the same time, the use of new plant-origin matrices for probiotic delivery is convenient, especially for those intolerant to milk (or its derivatives), for those requiring low-cholesterol diet and given the increasing popularity of food trends like veganism [14,15]. The results of some studies indicate also that frozen plant-based desserts may be a good carrier of probiotic bacteria [16–19]. The reliance upon the process of freezing functional desserts in production technology allows for the final product to be attractive. These products, with a high nutritional value and containing probiotic bacteria, are available to consumers throughout the year. Meanwhile, some health-promoting plant raw materials are available only seasonally. Despite the many health benefits of eating probiotic foods, the functional food market is still facing many challenges. The first group includes technological aspects such as the bioavailability and efficacy of probiotic microorganisms, their survival during manufacture and processing and, in the final food product, suitable texture and sensory quality can also be included. In contrast, the second group concerns the equally important consumer acceptance, storage and distribution that influence access to the global market. Recent developments in functional food have heightened the need for further investigation into manufacturing novel products for various consumers. The circumstances of production and preservation of these products need to be surveyed as well [20]. The scientific papers on challenges in the production of probiotic frozen desserts [21] and the issue of probiotic viability in frozen food products [22] are available in the current literature.

In response to the above considerations, the objective of this study was to conduct a literature review concerning the impact of various factors on the quality of functional frozen desserts based on plant-origin raw material, considering the authors' own experiments.

2. Factors Affecting Quality of Frozen Plant-Origin Desserts with Probiotic Bacteria

The different factors affecting the quality of frozen plant-origin desserts with probiotic bacteria are shown in Figure 1 and then discussed in the subsections below.

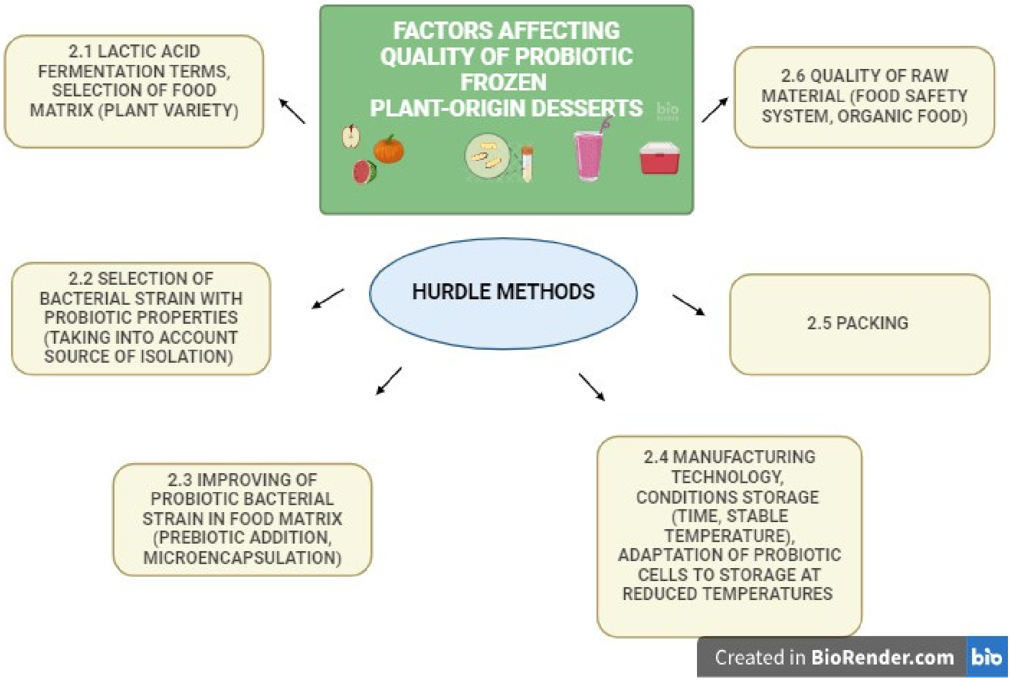

Figure 1. Factors affecting quality of probiotic frozen plant-origin desserts. Created with BioRender.com. Explanations: The numbers visible in the figure correspond to numbers of subsections.

2.1. The Lactic Acid Fermentation Process and Choice of Food Matrix

Food preservation is ecologically friendly, natural and produces goods with more nutritious content and a broader variety of tastes. The history of successful food preservation spanning thousands of years attests to this approach. It consistently attracts more and more attention and popularity while satisfying customer preferences and expectations [23,24].

Fermented foods are defined as "foods or beverages produced through controlled microbial growth, and the conversion of food components through enzymatic action" [25]. Food quality is a multivariate notion: foods carry an image of tasting good and being good for health. Taste and health-giving qualities need to be improved in parallel. Apart from the long-standing lactic fermentation method of food preservation, food preservation is also used to enhance sensory properties (e.g., taste and texture) with some foods, such as olives, which are inedible without fermentation that removes bitter phenolic compounds. Fruits and vegetables contain high levels of beneficial substances (e.g., antioxidants, vitamins and minerals), and also prebiotics, but the application of probiotic LAB can also bring about additional health-promoting benefits. Several mechanisms through which fermented foods may exert beneficial effects on human health are distinguished. The first is related to the participation of lactic acid bacteria in fermentation, including probiotic and potentially probiotic bacterial strains and the resulting benefits. During lactic acid fermentation, the enzymatic activity of the raw material and the metabolic activity of the microorganisms used can change the nutritive and bioactive properties of food matrices [26].

In plant-origin material fermentation, the growth of LAB enhances the conversion of phenolic compounds such as flavonoids to biologically active metabolites via the expression of glycosyl hydrolase, esterase, decarboxylase and phenolic acid reductase [27]. The combination of plant material and probiotics in a food product can provide consumers with microbiota in addition to the beneficial source of fiber and thus outlines a new direction for the design of probiotic foods in the future. Previous studies report that several anti-nutrients including phytic acids, tannins, protease inhibitors or polyphenols were reduced due to millet grain fermentation [28] legume fermentation [29] and cereal fermentation [30].

The goal of probiotic food has historically been to merely sustain cell viability in order to assure its effective function. But it is becoming more and more clear which bioactive metabolites—known as postbiotics—are unique to probiotics. Therefore, in order to guarantee that the items contain probioactives will improve health functionality, it is suggested that by modifying fermentation techniques to yield large concentrations of probioactives in supplements or fermented foods, probiotics can be made to operate better.

The microorganisms responsible for food spoilage and foodborne pathogens cannot thrive when exposed to LAB that produce bacteriocin. Additionally, probiotics must show that they have several advantages for food, such as preventing spoiling [31,32]. Accordingly, *L. plantarum* strains with their probiotic qualities can have significant impacts on dangerous microflora (foodborne pathogens) to extend the safety and shelf life of fermented foods, according to Sudhanshu et al. (2018) [33].

The literature data clearly show the huge potential for lactic fermentation to improve nutritional value, the safety and/or sustainability of fruit and vegetables, and the development of novel functional food products [34–37].

Probiotic cultures can be added to frozen desserts based on their chemical composition (lipids, proteins, vitamins and carbohydrates) [38]. The results of several studies [17,19,27,39] indicate an increase in the level of free amino acids, hydroxy fatty acids and antioxidant activity as a result of lactic acid fermentation process in plant-origin material.

Fermented foods of plant origin have been increasingly considered as a vehicle for probiotic bacteria delivery [40–43]. In order to obtain a probiotic frozen dessert, the raw material may undergo lactic acid fermentation or another solution may be used in the form of supplements with selected bacterial strains. Lactic acid fermentation can use several different techniques. Foods can be fermented naturally, often referred to as “wild ferments” or “spontaneous ferments”, whereby the microorganisms are present naturally in the raw food or processing environment, as seen for example in sauerkraut or kimchi. The second method involves the addition of commercial starter cultures (CSCs), known as “culture-dependent ferments” [44]. The next possibility represents natural fermentation with natural starter cultures (NSCs) but optimized through back-slopping, i.e., inoculation of the raw material with a small amount of an earlier successful fermentation. Repeated cycles of NSC practice can contribute to choosing bacterial strains with the best technological characteristics that are desirable for use as the starter culture [44,45].

Currently, the most popular plant raw materials used for fermentation include soya, cereals, vegetables and fruits. Fermented juices and fruit or vegetable pulp may be used as a semi-product form for the manufacture of frozen probiotic desserts. The cultivar, origin and ripeness degree of fruits are the factors that most influence the fruit quality and derivative products, such as sorbets [46,47]. Some studies also indicate that functional frozen probiotic desserts may be obtained by supplementation with probiotic bacterial strains, using riceberry and sesame milk as a base, instead of vegetables and fruits [18,48–50].

Fermented foods are among the oldest forms of processed foods that are known to have survived in today’s modern diet. They are produced during the biotransformation of raw materials into the final product by the action of microorganisms. One of the most popular biotransformations is lactic acid fermentation, performed by a relatively wide range of bacteria called lactic acid bacteria (LAB) [51]. This process is still of interest to research [17,26,52–56]. Additionally, some promising innovations in the technology of the lactic acid fermentation process have also been proposed. Although lactic acid is often produced by batch fermentation with free microbes, Chen et al. (2020) [57] showed that repeated-batch fermentation with immobilized cells may provide a number of benefits over this process. The suitability of a novel bacterium immobilization method utilizing a renewable poly-L-lactic acid (PLLA) microtube array membrane (MTAM) for lactic acid fermentation was comprehensively assessed. Using a siphon method, an encapsulation effectiveness of 85–90% was achieved, and bacteria in more porous MTAMs produced more lactic acid.

2.2. Selection of Bacterial Strains with Probiotic Properties

It is crucial to remember that not all probiotic strains are appropriate for food fermentation, and caution should be used while selecting probiotics. When it comes to lactic acid fermentation, probiotic-containing bacterial strains should be chosen for their compatibility with the intended flavor profile as well as their capacity to flourish and ferment the particular food matrix. Food matrices are unprocessed materials that can be infused with probiotic bacteria to facilitate their growth and assimilation into the food product. The most important criteria for probiotic functional food relate to maintaining the viability of the bacterial cells during the manufacture and storage of the developed products. It is known that the probiotic qualities and health advantages vary depending on the strain of LAB [58]. For probiotic food products to have the necessary beneficial effects, they must have a high concentration of microbe cells ($\geq 10^6$ colony forming units (CFU mL^{-1}) or 10^8–10^{11} CFU per day [59]. Food should continue to contain this many bacterial cells for the duration of its shelf life. Probiotic cells need to be able to survive their passage through the digestive system, accumulate in the colon and then attach to and colonize the intestinal epithelium [24,47,60].

However, because of the freezing, freezing storage and air incorporation processes, the frozen dessert manufacturing process may reduce the probiotic survival in the goods [48]. Prebiotic substances may shield the beneficial cultures during production, storage and simulated gastrointestinal conditions. Probiotic cultures and prebiotic compounds used together create synbiotic products [61,62].

In general, probiotic bacterial strains are isolated from humans, being found in substances such as feces and breast milk [63,64]. Until recently, only lactic acid bacteria isolated from the human gastrointestinal tract were recommended for human use as probiotics. However, some studies suggest that bacterial strains with probiotic characteristics can also be distinguished from fermented products of plant or animal origin [65–68].

A wide diversity of microorganisms is associated with the huge diversity in raw materials, fermentative behavior and obtained products [69]. However, the use of selected commercial starter cultures (CSCs) (for example, *Lb. acidophilus* La-5: *Bifidobacteriumanimalis subsp. lactis* BB-12) for lactic acid fermentation is beneficial and allows the achievement of reproducible product quality in successive batches. However, fabrication defects lead unerringly to economic losses as a result of the time wasted, the loss of raw materials and, most importantly, the loss of consumers' trust. The application of CSCs also results in consistent fermentations and process conditions (i.e., time, temperature, sugar or prebiotic added) that are important to produce high quality fermented food. To obtain functional products, probiotics must survive the food processing operations, packaging, storage or distribution process [70,71]. Improving the safety, quality and acceptability of fermented foods, while reducing their production costs, is important. This effect can be guaranteed by starter culture application and greater attention to food safety, such as HACCP approaches [72].

Although lactic acid fermentation is one of the oldest methods of food preservation, the link between these issues and the industry is still facing many technological challenges. It seems vitally important to use probiotic bacterial strains isolated from food to the plant origin raw material fermentation [66].

2.3. Improving Probiotic Survival in Plant Matrix Food

In the human body, probiotic microorganisms affect the function of the gut; therefore, it is important to select the appropriate strain and to take into account the various factors that affect its viability. A variety of stress factors (e.g., osmotic pressure, heat, low pH, gastrointestinal conditions, reduced water activity, nutrient depletion) during processing and storage as well as upon their transit through the gastrointestinal tract can influence the viability of probiotic bacteria, thus limiting their functional properties [26]. There are various techniques used to adapt probiotics. It is important to select probiotics, to supplement raw materials with nutrients. The literature provides evidence on the subject of encapsulation methods for microbial cells, in order to protect them against different environmental stresses.

In addition to the safety, technological and physiological criteria, the functional criteria of the selection of probiotics in commercial applications are very important. This group includes factors such as tolerance to gastric acid, bile tolerance or adhesion to the mucosal surface [73]. The resistance of probiotics towards bile salt and acidic conditions can be improved with the use of cereal milk (i.e., soy milk) as a medium and carrier [74].

2.3.1. Microencapsulation

Microencapsulation (ME) is a process in which probiotic cells are incorporated into an encapsulating matrix or membrane. This can protect the cells from degradation by the damaging factors in the environment and release them at controlled rates under particular conditions. In practice, the most commonly used coating materials are carrageenan, chitosan, cellulose, acetate phthalate, alginates, starch and milk proteins. When designing functional food for vegetarians, vegans or people with lactose intolerance, care should be taken to use coating materials with probiotic microencapsulation [75,76].

The use of hydrocolloids in probiotic microencapsulation is a widely used method for enhancing survival in ice cream during frozen storage [77]. Several studies show the positive impact of the microencapsulation process on the survival of probiotic bacteria in functional frozen products [77–80]. On the other hand, Silva de Farias et al. (2019) [81] suggest that the microencapsulation process is not advantageous for all probiotic species. Therefore, considering cellular losses, the best option for preparing functional yellow mombin ice cream is the application of *L. rhamnosus* and encapsulated *L. casei*.

The main microencapsulation technologies used for the encapsulation of microorganisms with probiotic properties are shown in Table 1.

Table 1. The main microencapsulation technologies used for the encapsulation of microorganisms with probiotic properties.

Method	Practical Application of Method	Features of the Method	Reference
Electrospraying	*L. plantarum*	Convenient and fast, mild conditions, strong adaptability and easy to scale up.	[82,83]
Extrusion	*Bifidobacterium subsp.* lactis (BB-12)	Low cost, simple operation, mild conditions and uniform size, but the production yield is small and the particle size is larger; difficult to use in large scale productions.	[84,85]
Layer-by-layer	*L. plantarum* 550	High controllability and adjustability.	[86,87]
Emulsification	*Bifidobacterium longum*	The production is easy to scale up, suitable for industrialization and the particle size is smaller, but there may be residual oil and the droplet size distribution is not uniform.	[88,89]
Freeze-drying	*Lactobacillus acidophilus* KBL409	The product stability is good, suitable for embedding thermosensitive materials, but it is expensive, has a complicated operation and the surface of the product may wrinkle and shrink.	[90,91]

2.3.2. Fortification with Prebiotics (Synbiotics)

Foods containing probiotics and prebiotics are among the best-selling functional foods around the world. For this kind of foodstuff to be successful, the inclusion of the prebiotics and probiotics should not detract from the consumers' liking of the food product or impart negative sensory properties in the food product [92]. For prebiotics to serve as functional food ingredients, they must not negatively affect the sensory properties of the product and are required to be chemically stable in food processing treatments, such as heat, low pH and Maillard reaction conditions [93]. Inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS) and xylooligosaccharides (XOS) are the most studied and well-established carbohydrate-based prebiotics. However, some non-carbohydrate compounds (minerals, polyphenols, or polyunsaturated fatty acids) have also been proposed as prebiotic candidates [94].

Prebiotics also improve sensory features, like freshness and taste, and they provide a more well-balanced nutritional composition because they are often used as dietary fiber (DF) and added as a low-energy bulking ingredient [95,96]. Moreover, the sensory properties of fermented probiotic frozen desserts are significantly improved by the fermentation process. The effects of probiotics on the sensory traits of frozen plant-based desserts rely upon the selected bacterial strain, terms of the fermentation process, food matrix used, storage temperature, addition of other compounds or freezing technique used. In the case of fermented products, the pH is low, which may affect the sensory acceptability, and it can be reduced by the addition of prebiotics such as an inulin or oligofructose [97]. However, some authors do not note the effect of the prebiotic additive on the sensory quality of frozen probiotic products, as opposed to the sucrose used [98].

From a technological point of view, additionally, the supplementation of the raw material with prebiotics before the fermentation process increases the number of bacteria in the final product. Balthazar et al. (2018) [99] have demonstrated that the prebiotic characteristics of inulin serve as a protective barrier for probiotics, which minimizes the severity of cell damage caused by environmental stress. Previous studies have also indicated that the addition of prebiotics has improved the growth of various probiotic bacteria in fermented frozen products [100,101].

The association of one (or more) probiotic with one (or more) prebiotic produces synbiotics, whereby the prebiotics and probiotics have a complementary and synergistic effect, thus presenting a multiplicative factor on their individual actions. The synergistic relationship between probiotics and prebiotics can enhance the production of metabolites so called postbiotics, which are gaining increasing importance because of their beneficial functions in the gastrointestinal tract and their influence on different organs and tissues. Notable among the postbiotics is gamma-aminobutyric acid (GABA), which plays an essential role in the prevention of neural disease, type 1 diabetes, cancer, immunological disorders and asthma [102]. The decarboxylation of glutamate causes bacteria to produce GABA. Both *Bifidobacterium* and *Lactobacillus* are characterized by their large number of GABA-producing strains, which has caused them to receive a significant amount of attention. Different parameters influence the expression of gad (glutamate decarboxylase) genes (and thus GABA production) with respect to the natural environment of each lactobacillus strain [103–106].

It is possible for the addition of various prebiotics to alter the textural qualities of food products, which are among the most significant sensory aspects of food and have a direct impact on the mouth behavior of the consumer as well as on how the food is perceived and enjoyed. The prebiotics that may affect food texture are mainly fibers, which can change the food structure and rheological behavior. This is because they start interacting with proteins and other polysaccharides, forming strong structural networks. Furthermore, the impact of these compounds on the texture depends on the type of prebiotic used and the interactions with the food matrix [107–109]. A summary of the applications of different prebiotics in functional frozen desserts is shown in Table 2.

Table 2. Impact of different prebiotic ingredients on quality of synbiotic frozen desserts.

Frozen Dessert	Applied Prebiotic	Main Effect	Reference
Fruit tea sorbet	Oligofructose (added after fermentation)	The prebiotic used caused the improvement of the overall sensory quality of fruit tea sorbets. Sorbets with 2% of oligofructose added were characterized by a smoother texture compared to the control sample. After 12 weeks of storage, the synbiotic sorbets were rated more highly than the probiotic sorbet.	[110]
Pumpkin dessert	Inulin (added before fermentation)	Hollow spaces were observed on the surface of pumpkin–pineapple desserts with 2% and 3% inulin addition, which could be the consequence of ice sublimation on the internal walls of the containers. The appearance of a gritty structure in the products tested in the course of the storage process could be explained by the sugar crystallization process. Pumpkin–pineapple sorbets and sorbets with 1% inulin addition were characterized by a detectable pumpkin taste and smooth consistency and the highest overall sensory quality marks.	[103]
Passion fruit-flavored dessert	Polydextrose/Oligofructose (added when combining all ingredients, technology without fermentation)	These prebiotics resulted in products with a higher melting rate and altered fruit-flavor, oligofructose texture and color parameters, with greater functionality (bioactive compounds) of ice cream and and decreased health indices for the hypercholesterolemic saturated fatty acid index cream processed (and increased desired fatty acid index). Ice cream with long-chain inulin presented a lower consistency while products with medium-chain inulin had improved volatility and profile (appearance of 2-butanone,3-methyl, fruity aroma).	[111]
Riceberry and Sesame-Riceberry Milk Ice Creams	Inulin (added when combining all ingredients, technology without fermentation)	The prebiotic addition caused protective effects towards probiotic growth and metabolism; the final products showed higher resistance to simulated human gastric conditions.	[18]
Frozen desserts based on Soluble extract of rice by—product and *Spirulina platensis*	Polydextrose (added when combining all ingredients, technology without fermentation)	The use of prebiotics resulted in a more consistent and cohesive texture and higher melting rates.	[112]

2.4. Manufacturing Process and Storage Conditions

Freezing is a method that is used to stabilize microbial starter cultures and probiotics during shipping and storage [102]. Frozen products may, therefore, be good carriers of probiotics. However, during the freezing, hardening and storage of frozen desserts, transport losses in the number of bacteria can occur. According to Motyl et al. (2019) [113], lactic acid bacteria are anaerobes or microaerophils and oxygen contained in air bubbles formed during the freezing process of the ice cream mixture in the freezer is an important factor impeding the survival of probiotic bacterial strains in ice. On contact with water, oxygen is partially reduced to a form of peroxide (O_2^-) and hydroxyl ion (OH-), which damages the proteins, lipids and nucleic acids, leading to cell death of the bacteria. The freezing technique used and the terms of the final product storage are, therefore, important factors affecting the quality of functional frozen plant-based desserts. These processes are crucial given the maintenance of an appropriate level of probiotic bacteria in the final products, but also given other qualitative aspects such as their good texture, sensory quality and nutritional value. One of the prospective directions of processing fruits, berries, vegetables and other products is the cryogenic processing of raw materials using cryogenic "shock" freezing (at a temperature lower than −60 °C) and cryogenic comminution. The use of this method allows the highest degree of preserving vitamins and other BASs (biologically active substances) [114,115].

The determination of physiological factors, i.e., the ability to grow and survive under different temperature conditions, is an important criterion for the suitability of LAB strains. If probiotic organisms are not present in the product in a sufficient viable concentration at the time of consumption (generally 6 log CFU/g), the potential probiotic health benefits will not be conferred on the consumer [59,60].

The stress resistance of bacteria is affected by the physiological status of the bacterial cell and environmental factors such as pH, salts and temperature. Low temperature affects the slowing of the biological processes of lactic acid bacteria (LAB). A reduction in incubation temperature induces adaptation processes in LAB cells, consisting of the inhibition or reduction of the synthesis of most proteins and the activation of cold shock proteins (so-called cold-induced proteins (CIPS)). There is a reduction in cell membrane fluidity, transcription and translation activity, and in the efficiency of protein-fold processes and the functionality of ribosomes [116].

Derzelle et al. (2003) [117] reported that cold shock proteins (Csps) were detected during the incubation of *L. plantarum* at 8 °C and were characterized as factors for cryotolerant cells: CspL was assigned a role in mitigating the effects of reduced growth rate and adaptation to temperatures slightly lower than optimal. CspC is associated with cell adaptation and regenerative processes, while CspP over-production can support cell viability during cold storage. Lactic acid bacteria are therefore able to grow after the incubation temperature has been reduced by 15 °C and more, although at a slower rate.

Other studies show the exposure of *L. plantarum* cells to low temperatures aids their ability to survive through subsequent freeze–thaw processes and lyophilization. Authors suggest that the strain *L. plantarum L67* adapts to low temperatures by a constitutive expression of the potentially cryoprotective CspP gene and proteins related to metabolism and stress response [118].

Recent studies have shown positive results regarding the growth and survival of probiotics in frozen desserts, especially in relation to the cold shock response due to increases in the ability to adapt to the low temperature of the final product during storage [16,18,19,22,103,112,119].

The manufacturing process of sorbets follows the incorporation of small amounts of air, making it a dispersion of ice crystals randomly distributed in a freeze-concentrated liquid phase. The quality of sorbet and ice cream is determined in part by the ice crystal size distribution (CSD) of the product. A narrow ice CSD with small ice crystals (<50 µm) is desired to confer a smooth texture and good palatability on the product. Therefore, it is important to identify the operating conditions that affect most directly the ice crystal size, so as to improve the quality of the final product [118–120].

One of the challenges in the process of storing ice cream is to maintain a constant temperature that has a significant impact on the quality of the product. Even small variations in temperature contribute to the initiation of the process of the recrystallization of ice. The solution to the problem of excessive increases in ice crystals during frozen storage is to choose a stabilizer that works in two ways: it absorbs water and reduces its contribution to the ice mixture and increases the viscosity of the system, thus reducing the diffusion of the free water [121]. Basic types of stabilizers added to frozen desserts are of two sources: animal sources (gelatin from bones and calf skin) and plant or vegetable sources (gums, agar-agar, carboxymethyl cellulose, sodium alginate, acacia, oat, carrageenan and karaya). The water-binding capacity of stabilizers is very high, and the stabilizers are added in small quantities; hence, the effect on flavor and product value is inconsequential. Total solids, processing machines, stabilizer properties and some other factors affect the usage of stabilizers. Therefore, stabilizers have the following functions: to smoothen the texture, provide body to the product, enhance viscosity, prevent texture coarsening, and provide resistance during melting with affecting the freezing point. However, the use of stabilizers may also involve certain negative effects on products like a heavy and soggy structure, restricted whipping ability or undesirable melting properties [122,123].

Carrageenan hydrolysates can not only be used for dairy products, but can also have positive effects on products such as sorbet without the addition of any milk proteins. This is important for optimizing frozen dessert production, especially regarding the temperature and time of freezing modifications [124]. On the other hand, Arai et al. (2021) [125] reported that *Enoki* mushroom extract was found to retard ice crystal growth and reduce the quality changes in ice cream during frozen storage. The literature also reports on new methods of analysis of the microstructure of frozen desserts such as X-ray microtomography using a thermostatic box [126]. Despite the health benefits of probiotics, some strains may also change the food texture, which seems to be mainly related to the production of exopolysaccharides by lactic acid bacteria (LAB). Prebiotics and probiotics can impact the food texture, which may be manipulated to develop novel products with the desired texture [108].

2.5. Packaging of Functional Products

Food contact materials (FCMs) are all those materials and articles intended to come into contact with food. FCMs play a key role in the production, processing, storage, transport, preparation, serving and consumption of food [127]. Laličić-Petronijević et al. (2017) [128] reported that seal leakage identified as a defect of packaging material could be considered a contributor to the decline of viable probiotic cells.

In commercial applications, for example, in restaurants, the period that the ice cream stays outside the freezer is much higher than, for example, in households, and therefore the quality of the ice cream decreases. Using phase-change materials (PCMs), packaging for ice cream containers showed significant benefits in minimizing the temperature rise of the ice cream [129]. According to Du et al. (2018) [130], PCM packaging can be efficient in catering applications to avoid the breaking of cold chains during transportation for quick frozen food, milk, ice creams and other products.

Some authors emphasize the impact of the type of packaging used for frozen desserts on life cycle assessment. Konstantas et al. (2019) [131] stated that Polypropylene (PP) ice cream tub is a notable hotspot for fossil fuel depletion and primary energy demand, contributing 22% and 19% to the total, respectively. High-density polyethylene (HDPE) is also used extensively in manufacturing and in the food sector in general and it could be used instead of polypropylene (PP). Both materials have similar densities. The packing mode of frozen food during its distribution and storage is a key aspect, since the food is expected to maintain its temperature within close limits, thereby ensuring its optimum safety and a high-quality shelf life [132].

2.6. Quality of Raw Food Material

The development of the functional food products market is an extremely dynamic field. There are many external factors that affect the process of food production. These include, among others, quality, price, the availability of both semi-finished products and raw materials, legal regulations and consumer preferences. The effective management of semi-finished products and raw materials is extremely important for the effective production of functional food. Semi-finished products are often used in various stages of production, and raw materials are the basis for creating final products. Proper planning, the control of stock levels and the timely delivery of semi-finished products and raw materials are key to maintaining the continuity of the production process and meeting customer requirements for the appropriate quality of the final product. Good manufacturing practices are essential to producing safe food for the public, increasing the chances of customer satisfaction, regulatory approval and business success [133].

The quality of plant-based raw food materials can also be tackled from the perspective organic production methods. Organic foods and goods are created from materials that are grown organically and are generally processed using mechanical, biological and physical methods. Because controlled production practices are followed, organic foods are free of pesticide, artificial fertilizer and heavy metal residues. As a result, most scientific research focuses on the quality of organic food and these substances to confirm their safety. Standard organic agricultural techniques are used to organically develop and produce organic foods, whose production depends on biodiversity, natural cycles and ecological processes [134,135].

With the growing interest of consumers in organic food, it was necessary to amend the regulations on organic production. The changes entered into force from 1 January 2022. The essence of the amendment was to replace in its entirety the existing regulation no. 834/2007 [136] on organic production and require the labelling of organic products under a completely new act, namely regulation 2018/848 [137]. The aim of the new act was primarily to clarify the regulations on organic production, which resulted in a significant extension of the regulations. As a result, the new regulation 2018/848 contains a number of detailed regulations regarding individual types of organic production covering plants, animals, beekeeping and processing. On the one hand, the development and detailing of the provisions clearly determines many issues that had previously been disputed due to the lack of clear regulations (such as the status of hydroponic production), but on the other hand the multitude of regulations significantly hinders their application [138,139].

As per the European Parliament's Regulation (EC) no 178/2002, "Food traceability" refers to the ability to track the past of a food product and is considered a crucial procedure in guaranteeing food safety for global customers. Only when the complete traceability of raw materials, semi-finished goods and procedures is guaranteed at every link in the food chain can the safety of produced food be preserved [140].

Over the past century, there have been substantial changes in the food product and supply chain landscape. Localized and seasonal food products have given way to complex food products that feature a wide variety of components from around the globe. More recently, technological advancements have made it possible to record and communicate data about the ingredients of food products at every point of the food supply chain, enhancing traceability. Internal and supplier traceability have been integrated into quality control systems by large organizations, and there are indications that most large manufacturers and retailers in industrialized nations are starting to do the same. It should also be stressed that food products create a significant impact environmental impact over their lifecycle [141].

3. Examples of Plant-Based Frozen Desserts Developed in the Authors' Own Experiments

In the laboratory of the Department of Technology Catering and Food Hygiene at Warsaw University of Life Sciences, an attempt was made to develop functional frozen plant-origin products such as fruit tea sorbets and pumpkin sorbets. The results of the qualitative assessment of the obtained products confirm those found in previous studies [109,110,142,143].

It was found that it is possible to manufacture probiotic fruit tea sorbets fermented with probiotic bacterial strain *L. rhamnosus* ŁOCK 0900 and with an oligofructose as a prebiotic additive. The count of bacteria did not drop below the minimum therapeutic dose (i.e., 6 log CFU/g of product) during the course of the items' storage. The sorbet that had 2% oligofructose added was found to have the highest level of *L. rhamnosus* ŁOCK 0900 bacteria (8 log CFU/g of product) out of all the goods that were stored for 12 weeks at −30 °C. The pH value of the designed products was 3.5–3.7. Based on the obtained results, it can be concluded that the time (12 weeks) and storage temperature did not affect the changes in pH value. On the other hand, the addition of the prebiotics resulted in a significant decrease in the pH value of the control sample. The overall sensory quality and texture of the items improved as a result of the oligofructose addition to the recipe [109].

On the other hand, we also developed fermented pumpkin sorbets with one probiotic bacterial strain *L. rhamnosus* ŁOCK 0900, concentrations of 17% added sugar and inulin, with or without pineapple juice addition. The developed pumpkin sorbets, after 6 months' storage at −30 °C, were characterized by good sensory quality and contained an appropriate probiotic bacterial number (higher than 8 log CFU/g of product) and, therefore, could be considered as potentially functional products [110].

The results obtained as part of the continuation of research on the optimization of the composition and quality of innovative functional desserts based on pumpkin confirm that the selected freezing technologies: ((1) classical freezing, (2) dry ice and (3) liquid nitrogen) affect the level of sensory quality and the number of LAB marked in frozen desserts but do not differentiate between these products taking into account the value of antioxidant activity. Statistically, the highest number of LAB ($p < 0.05$) were recorded in the case of samples produced using liquid nitrogen technology (8 log CFU/g) compared to other technologies (using dry ice (7.8 log CFU/g) and classic freezing (7.5 log CFU/g)). The process of lactic acid fermentation with LAB (*L. rhamnosus* ŁOCK 0900) an increase of several times in the level of antioxidant activity, which confirms the participation of functional additives, i.e., probiotics, in the positive shaping of the quality of functional food products. The type of production technology used determined the pH value of the finished products. The lowest pH value of all the fresh samples tested was recorded for sorbets produced using the dry ice technology (value 4.9). There was no significant differentiation ($p > 0.05$) between products produced with the other technologies, i.e., traditional and liquid nitrogen, in terms of pH value (mean value 5.5). Changes in the pH value of the investigated products were not statistically significant during 16 weeks of storage at −18°C [142].

In other study [143], the impact of the source of origin of the applied LAB strain with probiotic properties (isolated from food, environmental origin—*L. casei O14*; derived from human—*L. rhamnosus Lock 0900*) and the variety of plant raw material on the quality of the finished product was assessed, based on the example of pumpkin sorbets, for which, regardless of the pumpkin variety used, the process of lactic fermentation of pumpkin purees with selected strains of LAB with probiotic properties resulted in a reduction in the content of total and reducing sugars, total carotenoid content and increased antioxidant activity in finished products compared to raw pulp. All the sorbet samples were characterized by a high number of LAB (over 8.5 log CFU/g) and good sensory quality (overall sensory quality rated above 7 c.u). It was observed that, regardless of the raw material variety used, fermented products made with the participation of a strain isolated from food of plant origin, *Lacticaseibacillus casei* O14, were characterized by a significantly higher number of LAB compared to fermented sorbets with the participation of a commercial reference strain—*Lactobacillus rhamnosus* ŁOCK 0900. Sorbets prepared using the pumpkin variety "*Melonowa Yellow*" (*Cucurbita maxima*) were characterized by a significantly higher ($p < 0.05$) content of carotenoids, total content of sugars and value of antioxidant activity compared to the variety "*Miranda*" (*Cucurbita moschata*). The pumpkin variety and the LAB strain used with probiotic properties, used to ferment pumpkin purees, affect the recorded number of LAB in the final products, the composition of bioactive compounds and the antioxidant activity and sensory quality of functional frozen pumpkin desserts. The developed technological solution in the form of functional pumpkin sorbet has been patented [144].

On the basis of the above-presented results of the authors' own research, it can be concluded that the selection of strains of bacteria with probiotic properties for the fermentation process should take into account the technological suitability including, among others, good survival in a given food matrix, during the production and storage of the finished product. The selection of the optimal strain of probiotic bacteria should also take into account the source of its isolation, in terms of obtaining a functional end-product of acceptable microbiological, sensory and physicochemical quality. The present results of our own studies confirm that probiotic and/or synbiotic, frozen pumpkin desserts show promising potential for utilization as functional products.

4. Conclusions and Future Trends

The inspiration for the writing of this review has been the trends in the frozen food market and an increasing consumer awareness observed in recent years. More attention is being paid to the relationship between the type of food consumed by humans and their health, leading to the search for new, pro-health, so-called functional products. The market for probiotic products, dominated by dairy products, is looking for a new alternative in the form of plant products, due to the risks of intolerance of dairy products and the highly popular vegetarian lifestyle. Plant growers and food technologists are looking for new varieties, using forgotten and often undervalued plants and new processing technologies. The quality of probiotic plant-based frozen desserts depends on a number of factors, namely, raw materials, technology and hygiene. The selection of the plant matrix and the appropriate strain of probiotic bacteria are of fundamental importance. To maintain the viability of bacteria in products throughout the entire storage period, various techniques are proposed, namely, microencapsulation or the use of probiotics. This latter technology should be especially taken into account because it additionally increases the nutritional value of synbiotic products. We also cannot forget the need to ensure highly hygienic production conditions and the selection of appropriate packaging techniques.

It should be emphasized that the long-known process of lactic acid fermentation is a more favorable technological solution for improving nutritional value, compared to supplementing the product with LAB. However, based on the current trends, the idea of a frozen plant-based product is emerging, using raw materials that can be traditional and known but a new variety and the modification of the technology used so far (i.e., lactic acid fermentation with new environmental lactic acid bacterial strains; appropriate freezing methods; prebiotic addition and the possibility of obtaining synbiotic products; innovative packaging methods); this process will make it possible to enrich the offer of frozen functional desserts available on the market.

The future success of functional frozen food in the market first of all depends on consumer acceptance of such products. Probiotic frozen plant-based desserts have promising potential for the development of functional food products. In summary, the possibility of using plant-origin frozen desserts as a probiotic carrier represents valuable alternatives in the functional product segment of the food industry with the right technological process and financial investment.

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