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Review

Sorbets as Functional Food Products, Unexplored Food Matrices, Their Challenges, and Advancements

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Abstract: Functional foods and beverages are becoming one of the leading food products on the global market today. This is predominately due to the consumer, industry and research-related interests in the use of food-derived products for the management of several chronic conditions. The diversity of currently available functional food products also provides an opportunity for the use of fruit-based sorbets as a carrier of functional ingredients. Therefore, the aim of this literature review is to explore the use of sorbets as a functional food product, which is one commercial method that can be utilized to provide health benefits, extend the shelf life of foods, and preserve nutrients and improve taste. Firstly, we provide an overview of sorbets as a functional food matrix, their development and implications for the absorption of functional ingredients in humans. We discuss the developmental considerations of functional foods, such as the technical conditions and physicochemical and organoleptic properties through which functional foods can provide beneficial health effects. These include product stability, metabolism of the functional food ingredient, its interactions with the food matrix and limitations related to its production. There is a paucity of clinical data that investigate the long-term health effects of products claiming additional functional benefits. Given the extensive potential benefits of functional bioactive food compounds and their heavy prevalence in the market, extensive research and further regulation is needed to ensure health recommendations for large populations in longitudinal clinical studies warranting any functional claim.

Keywords: functional foods; product development; nutraceuticals; sorbet; fruit ices

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1. Introduction

The development of functional foods and beverages is one of the key areas that combine innovation whilst targeting consumers' needs. Since their inception, functional foods have been defined or referred to as foods or beverages that claim to provide benefits beyond the existing nutrition found within the original product [1]. The value of the global functional food market (including beverages) was estimated at USD 203.64 billion in 2022 [2]. Along with the development of functional foods comes the increase in demand for various types of supplements, beverages and food products, which also drives this growth [3]. Furthermore, the consumer market for functional foods has shown continuous annual growth patterns, with values projected to exceed USD 229 billion by the end of 2023 [2]. The market for functional foods is predominately dominated by the USA (35%);

when combined with European countries (32%) and Japan (25%), these three markets contribute to approximately 90% of total functional food sales globally [4]. Japan initially pioneered the development of functional foods, with active sales of these types of foods since the 1930s. Furthermore, the increase in Japan's aging population is associated with an increased prevalence of health problems and related healthcare costs. This provided a rationale for the support of functional food research programs, prompting the development of foods for specific health uses [4]. The development and marketing aspects of functional foods are complex and often associated with the relatively high expenses required to create a new and innovative food product. In addition, several food production aspects must also be taken into consideration, such as the technical conditions and physicochemical and kinetic properties that will allow a functional food product to produce its beneficial health effects whilst minimizing the likelihood of risk to human health [5].

The addition of bioactive compounds to increase the functionality of a food product has attracted growing interest from the commercial food industry. Current research is only just beginning to unearth the potential health outcomes of combining functional bioactive compounds within marketable food items [1]. The health outcomes of functional food products range from prevention aspects related to various diseases to improving health status and potentially overall quality of life. Likewise, current trends in the food industry regularly change in response to consumer demand, and this is apparent especially in areas such as health and fitness. A key trend is the increased awareness and education surrounding the relationship between food constituents and health, resulting in food manufacturers shifting towards products that maintain a strong health position [6]. For instance, to promote healthy bone development, it is suggested that the consumption of calcium-rich foods is necessary in times of rapid physiological growth. Therefore, children who may not have access to calcium-rich foods or those presenting calcium deficiencies may benefit from the fortification of food products with calcium to increase bioavailability [7].

Numerous functional food products already exist, including dairy products, bread, juice and children's cereals, which are commonly found in regions such as North America, northern Europe, including the United Kingdom, and to some extent in Australia. The increased market requirements, variety of products and consumption of functional foods are also associated with the increase of health-conscious consumers as well as new and existing food consumption trends that contribute to the consumer maintaining a healthy lifestyle without adjusting their current dietary habits [8–11].

Functional food development must also address the health 'functionality' of the bioactive ingredient of interest, the benefits and interactions in the body and the safety and stability of the product. As such, several considerations must be taken into account during food product development, such as the stability of the product related to changes in pH, salt and sugars, the metabolism of the functional ingredient and the interactions between the functional ingredient and food matrix composition. Although all foods are considered 'functional' from a holistic perspective, it is essential to highlight that the active ingredients in their pure forms might not necessarily possess the same functionality once embedded in the food matrix or when consumed, thus warranting the need for clinical testing to investigate proposed functionality claims.

Functional foods can be grouped based on the composition and properties of the food matrix. Examples of these include food products that are purposely modified by enrichment with bioactive compounds, foods with bioactive components removed, added specialized synthetic food ingredients, or their combination [12]. Examples of these functional foods with their added ingredients include cholesterol-lowering margarine (phytosterols), cereals and juices (folate), dairy products (calcium enriched), yoghurts with added non-dairy probiotics, gluten-free foods (pea protein), sorbets, and more recently, the integration of different foods (hemp, kale) and various seeds (chia) and berries (acai) into food items (Table 1) [13–16].

Selecting a functional ingredient to address specific health problems is one of many steps in functional food development. For instance, plant bioactives have been investigated for their ability to improve cognition due to the presence of B vitamins [17] and curcumin [18], which show promise in delaying the progression of cognitive decline. However, more novel plant bioactives are frequently being added to functional foods to promote healthy aging, including a variety of different mushrooms [19], nootropic agents to improve health status [20] and the amino acid L-theanine (L-THE) to reduce stress outcomes and improve cognition [21,22].

Table 1. Selection of functional food ingredients and their proposed health claims in Australia and New Zealand.

Ingredient	Proposed Functional Food	Health Claim	Ref
Plant sterols and stanols	Margarine	Both plant sterols and stanols appear to lower blood LDL-C when consumed (1.5 to 3 g/day) with foods.	[23]
Folate/folic acid	Cereals	The prevention of embryological neural tube defects such as spina bifida and anencephaly.	[24]
Vitamin D and calcium	Milks and Juices	Fortification of Vitamin D and calcium potentially reduce future health burdens from osteoporotic fractures.	[25]
Iodine	Bread	Fortification of iodine in bread products in New Zealand positively contributes to 51% of iodine intake in developing children with a mean iodine intake of 35 µg/day.	[26]
Omega 3	Eggs	Consumption of omega 3-enriched chicken eggs may provide extended health benefits to consumers by increasing total omega 3 status.	[27]

Note: LDL-C; low density lipoprotein cholesterol.

Therefore, the specific aims of this brief literature review are to define functional foods from the existing literature and provide a detailed review of functional food vehicles and the considerations required for their development while investigating the physicochemical and formulation aspects of these food products with a specific focus on sorbet.

2. Functional Food Vehicles

There are a variety of existing functional food products available on the current market [7]. Numerous products exist in the Australian market, such as calcium-enriched milk (Paul's physical ©), cereals (Uncle Toby's Plus Calcium ©) and soy milks (PureHarvest Soy enriched with Calcium ©). Likewise, there is an abundance of functional foods containing folate as a prophylaxis for the in utero development of neural tube defects such as spina bifida and anencephaly [28–30], including juices (Berri Orange Juice ©), cereals (Kellogg's All Bran © and Sanitarium Weet-Bix ©) and extracts (Vegemite ©). In addition to the mandatory fortification of flour [7], there are also attempts to fortify a variety of functional frozen products, such as ice creams and sorbets, with bioactive ingredients. This includes amaranth-infused lemon sorbet [31], epigallocatechin gallate in strawberry sorbet [32], FroPro © whey protein chocolate ice cream, low-caloric ice creams (Halo Top ©) and Cornelian cherry-infused ice cream high in vitamin C [33].

2.1. Sorbet as a Potential Functional Food

Among the functional products such as breads, berries and vegetables, frozen foods such as sorbets consumed among global populations are gaining attention. Sorbets as a functional food is one commercial method used to provide health benefits, extend food storability, preserve nutrients and provide palatability to the consumer [34,35]. Specifically, the Food and Agriculture Organization (FAO) classifies sorbets as a frozen water-based dessert that comprise two main ingredients: fruit juice and sugar (among other ingredients) [36].

Recently, sorbets have been used as a vehicle to deliver compounds to the body. A recent article showed that amaranth proteins could be embedded within the matrix of lemon sorbet as a potential functional protein source to increase bioactive peptides and antithrombotic activity [31]. Likewise, avocado, kiwi, honey melon, yellow melon and mango sorbets have also been studied with the embedded prebiotic inulin, which ultimately increased the organoleptic and pro-health features of the sorbets [37].

An Integral part of the development of a functional sorbet is evaluating the stability of the food matrix and the functional ingredient in its storage environment to ensure that the functionality of the target ingredient is not compromised. Several properties of the sorbet must be considered, such as acidity, moisture content and the addition of stabilizers. Furthermore, the release kinetics of the incorporated bioactive is dependent on numerous factors, including food vehicle choice of juice, interaction with other compounds, overcoming absorption problems and the overall toxicity of the functional food ingredient. The addition of functional bioactives can also elicit undesirable flavors and potentially alter the overall stability of the product. Therefore, it is essential to consider the current trends that exist and create techniques to develop a functional food sorbet [38].

2.2. Developmental Considerations for a Functional Sorbet

2.2.1. Acidity

The optimal pH of functional food sorbets helps maintain their stability, assists with cost-effective production methods and avoids causing potential health problems. The pH of sorbets is dependent on the overall composition of the fruit juice, and to extend the shelf life as well as increase the integrity of the added ingredient, changing the pH environment is one of many different approaches used to maintain the stability of the added bioactive [39]. For instance, green tea constituents such as tea polyphenols and amino acids present a more comprehensive stability range in different pH environments in which they are highly pH-dependent (pH 3–6), especially favoring acidic conditions [40]. One example is the stability of the green tea amino acid L-THE, which is maintained between pH 5–6 in 'normal' conditions; however, the likelihood of degradation increases when placed into an environment outside its stability range. In contrast, different variations in pH can impair the food or beverage matrix. For example, during the wine aging process, if the pH during the bottling process does not fall between acceptable ranges (pH 3.4–3.8 for red wines), the aging of the wine may become compromised, resulting in a faulty product [41].

2.2.2. Moisture Content and Microbial Growth

Moisture content is one of the critical aspects considered when designing a functional food vehicle (in the form of a sorbet) due to its relationship with microbial growth and storage temperature [42]. Water activity (a_w) is a direct measurement of the degree to which water found within a food system is available to enable metabolic reactions [43]. In many fresh foods, the a_w exceeds 0.95, and over time the a_w may decrease slowly (postproduction) due to environmental conditions such as exposure to microorganisms, atmospheric conditions and sunlight, for instance. Furthermore, bacteria require a high water content environment to cause food spoilage ($a_w > 0.91$), with Gram-negative bacteria generally needing a higher a_w than Gram-positive bacteria, while fungi can grow in as low as a_w 0.80 [43].

The stagnating effect on microbial growth is believed to occur due to the lack of substrates in the food product required for exponential growth and the limiting factor of oxygen, which effectively starves microbes, leading to inactivation [42,44]. Regarding storage temperature, a frozen food vehicle such as sorbet is one delivery method that allows manufacturers to halt the activities of microorganisms that can potentially spoil the food product. Likewise, frozen foods are associated with fewer outbreaks of foodborne illness, potentially indicating that some microorganisms and pathogens can be killed by some commercial freezing process pre-treatments [45].

2.2.3. Reduction of Microbial Growth

Similar to the osmotic mechanism of salts, sugars in food decrease a_w [44]. Sugars act on cellular organisms via osmosis, drawing moisture out through a membrane to reach an equilibrium with the food product [46,47]. As a result, sugars have a profound effect on stagnating microbial growth. However, as sugars can be easily broken down through fermentation, it is essential to combine techniques such as freezing processes that halt microbial formation or implement the addition of stabilizers to prevent degradation of the food product. As a result, it is worth postulating that increasing the stability of a frozen functional sorbet matrix via the addition of microbial growth inhibitors such sugars may also increase the stability of the added functional bioactive compound and extend shelf life.

2.2.4. Stabilizers

Stabilizers are added to ice creams and sorbets to provide smoothness in body and texture, reduce ice crystal growth during storage, as well as increase the stability of proteins. A relatively recent example is the addition of cellulose nanofibrils, which are a fibrous banana extract that have reduced the melting rate as well as extended the shelf life of ice creams and improved their sensory properties [48]. A second example is the protective effects that sugars have over proteins exposed to heat treatments during manufacturing processes [49,50]. Sugars stabilize proteins by inducing hydration via hydrogen bonding mechanisms to folded protein structures by acting as a substitute for water [51], as well as inhibiting heat coagulation that causes denaturation [52]. Reducing sugars, such as trehalose, are considered as exceptional protein stabilizers, as they are not affected by color and flavor changes that occur during denaturation processes such as the Maillard reaction [49]. This is due to trehalose's structural rigidity, which allows this reducing sugar to show high heat and pH stability, as well as retaining enzyme activity in a solution in its freeze-dried state. Trehalose, in turn, is an ideal ingredient for use in the industrial food and pharmaceutical industries [49]. Examples of how this potentially can benefit human consumption are during the development of functional foods that contain added proteins and amino acids, which may become exposed to high heat. This includes dairy products prior to freezing, as well as heat-treating fruit juices as a base for sorbet production to eliminate microbes.

Similarly, foods that require below 0 °C storage conditions, such as ice creams and sorbets, benefit from the addition of stabilizers. Stabilizing sugars such as oligosaccharides can form more hydrogen bonds during freeze-drying processes, which decreases denaturation as well as improves packing density [53]. The addition of traditional stabilizers such as gums (guar, locust bean and cellulose gum) also influences the viscosity and rheological properties of ice creams, which reduce the degree of ice crystal growth and result in improved stability and texture [34]. Similarly, the addition of whey proteins into a sorbet acts as a stabilizer, as whey proteins have a strong water-binding capacity that results in less free water being available to crystallize during the freezing process [34].

3. Compound Interactions between the Sorbet Matrix and Digestive System

Metabolism of the Functional Ingredients

There are several molecules identified in foods that potentially react or interact with bioactive compounds, which can reduce bioavailability. Appropriate fruit selection to produce a functional sorbet is essential to ensure that the selected bioactive does not bind to the food matrix or interact with other compounds. For any bioactive to reach systemic circulation, it must pass several phases of digestion, which can lead to drug–food interactions and food–food interactions that disrupt the effectiveness of the added bioactive compound (Table 2). These interactions potentially affect the absorption, distribution, elimination and metabolism of the compound [54]. This commonly occurs when multiple compounds interact and have a synergistic or antagonistic effect on one another.

It is also important to consider metabolic systems responsible for the breakdown of substrates in the body, which can have synergistic or antagonistic effects on the body. For example, the cytochrome P450 (CYP), an essential system of haem-proteins, is involved in the oxidative and reductive metabolism of food and drugs in the body [55]. Enzymes of the CYP system can be inhibited or up-regulated by food intake and potentially lead to toxic concentrations of other consumed compounds in the body metabolized by the same

CYP system [56]. Consequently, this may inhibit or induce the absorption, digestion and dispersion of substrates into the body. Foods such as grapefruit juice (commonly used for sorbet) have similar effects to medications such as erythromycin, which are inhibitors of CYP and decrease CYP enzymatic activity, potentially leading to increased concentrations of other ingested substrates. Besides drug interactions, food–food interactions are known to increase the absorption of certain nutrients; however, their potential side effects vary (Table 3) [57–64].

Table 2. Interactions between commonly consumed endogenous or exogenous compounds.

Type of Interaction	Compounds	Type of Study	Finding	Reference
Drug–food	Cyclosporine and grapefruit juice	Systematic review and meta-analysis	Seven studies (n = 98) indicated that administration of grapefruit juice increased the plasma concentrations of cyclosporine.	[65]
Drug–food	St John's Wort and indinavir	Clinical trial	Fifteen-day oral administration of St John's Wort significantly reduced plasma indinavir levels in male Wistar Rats.	[66]
Drug–food	Angiotensin converting enzyme inhibitors and potassium	Review	Foods high in potassium must be considered by physicians prescribing angiotensin converting enzyme inhibitors to reduce the incidence of hyperkalaemia.	[67]
Drug–food	Rupatadine and high-fat breakfast	Clinical trial	Rupatadine, an antiallergic medication with dual peripheral antihistamine H1 activity, in combination with food increased rupatadines bioavailability.	[68]
Food–food	Coffee and iron	Cross-sectional study	Data from the Korean National Health and Nutrition Examination Survey (n = 27,071) indicated that increased coffee intake was strongly associated with decreased serum ferritin concentrations.	[69]
Food–food	Vitamin C and iron	Review	Vitamin C consumption aids in regulating iron metabolism by increasing transferrin and non-transferrin uptake and decreases cellular iron efflux.	[70]
Food–food	Vitamin D and calcium	Systematic review	Vitamin D increases intestinal calcium absorption; however, the use of vitamin D in association with calcium shows inconsistent findings regarding health outcomes such as bone health, cardiovascular disease and cancer outcomes.	[71]

Table 3. Interactions between vitamins and commonly prescribed medications.

Vitamin/Mineral	Drug	Type of Study	Finding	Reference
Vitamin C	Protein pump Inhibitors	Literature review	Vitamin C bioavailability is decreased when taken alongside protein pump inhibitors such as omeprazole.	[62]
Vitamin A	Neomycin	Clinical trial	The single dose (2 g) neomycin sulphate in combination with 30,000 i.u. Vitamin A decreased plasma retinol levels 4 h post-food consumption.	[60]
Vitamin K	Warfarin	Clinical trial	Patients with lower vitamin K status showed greater sensitivity to warfarin than those with high vitamin K status.	[61]
Vitamin D	Cholestyramine	Clinical trial	Adolescents with familial hypercholesterolemia consuming cholestyramine 8 g/day for one year showed significant decreases in serum 25-hydroxyvitamin D concentrations.	[63]
Vitamin B9 (folate)	Phenytoin	Systematic review	The administration of the anticonvulsant drug phenytoin showed significant decreases in serum folate levels in epileptic patients.	[64]

4. Overcoming Absorption Issues

4.1. Nanoencapsulation

Various factors could potentially alter the integrity of ingested functional food compounds. For instance, the compounds with low stability in high pH environments may have reduced dispersion, digestion and absorption into the body when exposed to high pH conditions such as those experienced in the small intestine (Figure 1) [72]. As a result, residual amounts of compounds that remain post-consumption may become insufficient to produce desirable, beneficial effects in a pH environment not suited to the specific compounds' pH stability range [73].

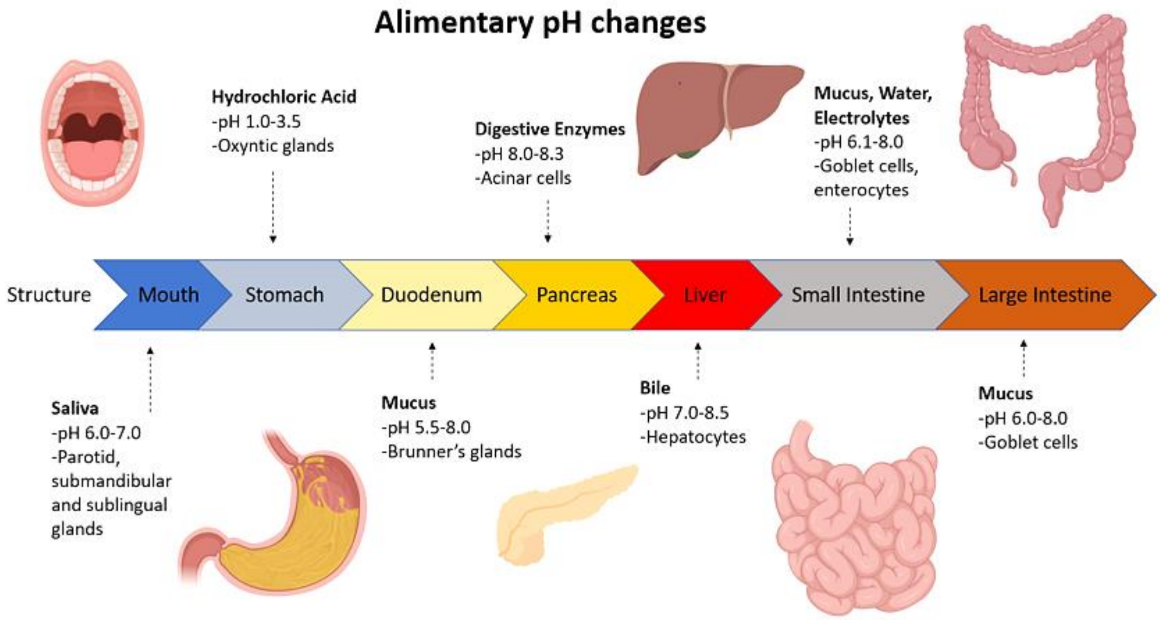

Figure 1. Consumed bioactive ingredients are subject to pH changes that occur through the human alimentary tract that can inhibit the activity of dispersion, digestion and absorption into the body. Images developed using Biorender.com (2021).

Nanoencapsulation is one of the methods that is used to overcome this potential issue. Nanoencapsulation works by the principle of entrapping the active ingredients in a core surrounded by secondary materials (proteins, minerals) to form a nano-sized-capsule, protecting the core from the environment. Therefore, this technique provides a promising rationale to overcome the degradation of the substance outside of its pH range within the gastrointestinal (GI) tract [74]. Furthermore, nanoencapsulation techniques in the food industry also allow greater product stability, enhancing flavor as well as increasing the overall bioavailability of a food item [74,75]. For instance, the stability of folic acid can be maintained when incorporated into iodized salts. However, it is suggested that folate incorporated within encapsulated premixes, especially with added salt, allows both active compounds to be separate. This has the potential to improve the stability and consumer bioavailability of the product [76]. These bioactive protective mediums can be permanent or developed so that changes in pH or differing enzyme activity can enable the controlled release of the core's constituents once consumed. One bioactive that could potentially be incorporated into functional sorbets using nanoencapsulation as an adjunct treatment for diseases including atherosclerosis, heart failure and Alzheimer's disease is curcumin. Curcumin has relatively poor chemical stability and low bioavailability (low water solubility and fast transient metabolism) and therefore has generated significant interest in the potential to be delivered via nanoencapsulation technology to improve absorption and thus improve treatment outcomes [77,78].

4.2. Lipid-Based Delivery Systems

Another method to overcome absorption problems is the use of lipids to carry compounds of interest around the body, also known as a 'lipid-based drug delivery system' (LDS). Although lipids are not commonly found in sorbets (as sorbets are water-based food products), the use and application of this technology is potentially transferable to the use of sorbets as functional foods. This technique has gained significant interest in the delivery of compounds that have low water solubility. The LDS technique improves the absorption and bioavailability of food bioactives via influencing factors such as dispersion, digestion and absorption [79]. Several functional food products already exist that utilize this method of delivery. Some of these include functional bread with enriched omega-3 fatty acids that incorporate high amylose corn starch to form nano complexes alongside flax seed oil incorporated into the bread matrix [80]. Lipid-based technologies are also applied as an approach to targeting the time-controlled and site-specific release of compounds that have varying molecular weights [81]. One of the benefits of this type of delivery system is responding positively to the integration of a surfactant, which can lower the surface tension and increase the dispersion and bioavailability of desired lipophilic compounds [82]. Therefore, incorporating bioactives into carrier particles is one method that may allow functional foods to overcome the inherent restraints faced when dealing with improving the bioavailability of bioactive constituents [78].

5. Trends for Functional Sorbets

5.1. Improvements in Product Acceptance

There are several considerations required for consumer acceptance of a food product. Moisture content contributes to the overall acceptance, particularly to the overall taste, texture and appearance at the time of producing the product and over the storage period [83]. For instance, the grittiness of ice creams or sorbets occurs due to poor manufacturing processes that result in the over-crystallization of solids and liquids, as well as lactose crystallization. Similarly, recrystallization (Ostwal ripening) and its formation in the post-production phase can be attributed to the change in temperatures during product storage due to melting of smaller formed crystals and the movement of the subsequent melted liquid to the surface of crystals with larger diameters [84–86]. Over-crystallization can be avoided through methods such as rapid cooling to the desired temperature below the melting point of that food product [35,87]. The same effect has also been observed in solid-state foods such as meats and vegetables through processes known as 'snap freezing' that aim to eliminate the formation of crystallized ice particles within the food matrix [88]. Other methods for controlling the ice particle formation in foods have also been tested, with promising results such as pressure shifting and ultrasonic and dehydro-freezing [89]. Similarly, methods that include the incorporation of so-called 'antifreeze' proteins that act as a cryoprotectant have also shown promising results by improving overall consumer acceptance with regard to improving texture and viscosity [88].

5.2. Enhancing Taste

Consumer acceptance of food products is also affected by additives such as salt and sugars. Salt content is mostly determined by the consumers preferentially [90], although, despite consumer influence, salt enhances the flavor profile of foods. Salt elicits suppression effects of bitter foods [91,92] by modulating interactions of a subset of taste receptors (TAS2R38) [38,93–95]. The addition of salt into functional food products can therefore be utilized when bitter compounds (cocoa flavonoids and green tea extracts) are added to the matrix [21,38,96,97].

Likewise, the favorable response humans have towards the taste sensation of sweetness is linked to the brain responses associated with pleasure, happiness and reward [49,98]. A variety of sweet compounds exist, such as sugars (mono-, di- and poly-saccharides) [99], sweeteners (stevia, xylitol, saccharine and erythritol) [100,101] and amino acids (D-tryptophan, L-THE) [21], as well as taste-altering proteins. The addition of sweet compounds in foods such as fortified dairy products (calcium and vitamin D), therefore, is one method to potentially increase the likelihood that the food product is consumed [102].

5.3. Health Trends

The trends towards healthier food consumption have increased rapidly over the past decade, mainly due to the rise in consumer food knowledge [103]. For instance, a study by Vella et al. (2014) administered a questionnaire regarding functional foods that assessed consumption, motivating factors for consumption and awareness of health claims. The study found that among older adults, functional food consumption was high. However, there is a need to improve transparency regarding functional foods in line with nutrition and health regulations such as those specified within the EU, where it is required that any nutrition claims are clear, accurate and based on scientific evidence [104,105]. It has also been postulated that sodium intake is one of the most common nutrients that potentially determine a consumer's increase in functional food consumption [106]. In one study, it was also noted that young participants were more likely to be influenced by the health attributes of a specific product, including fat and sugar content [106]. As such, current health guidelines are attributable to current food trends focusing on reducing salt consumption, especially considering the rise in mortality that currently occurs as a result of hypertension, cardiovascular disease and stroke [107,108].

Overconsumption of sugars is one underlying factor contributing to the rise in global obesity [102]. Obesity is a public health issue, placing a burden on public health systems and increasing healthcare costs and related health outcomes such as cardiovascular disease, stroke, metabolic syndrome, diabetes and cancer [109]. As a result, improving the health status of functional foods by lowering their total energy content through sugar reduction is one method that may drive consumer consumption, which can be achieved through the addition of low-energy natural sweeteners such as Stevia, erythritol and Monk fruit extracts into the food matrix [101]. One of the most significant difficulties in promoting the consumption of functional low-energy sweeteners is replicating the taste and texture of the 'original' products. The natural sweetener Stevia is produced from the South American plant *Stevia rebaudiana*, with a sweet flavor almost 200–300 times stronger than sucrose. The consumption of Stevia is related to having a bitter metallic taste associated with aspartame or erythritol, which it was combined with in its first-generation development. Other sweeteners such as maltitol are preferentially incorporated into ice creams. These compounds also reduce the total energy in foods whilst maintaining taste. New and innovative methods also exist, such as altering the molecular structures of sugar, allowing for better dissolving on the tongue surface to increase the sensation of sweetness whilst maintaining palatability [110].

The attribution of health benefits to a functional food must be based on thorough scientific evidence from well-designed clinical trials. In practice, this is highlighted by the recent trends of supplementing antioxidants into foods and powdered supplements to improve the functional characteristics of the product [111]. Current evidence also postulates that chronic consumption of these supplements can be detrimental to the body and in excess can potentially be carcinogenic [112]. Given the potential benefits of functional food bioactive compounds, extensive research is warranted to explore their proposed claims on health further.

6. Limitations

It is crucial to consider and implement the scaffold procedures required for functional food development to avoid negative implications and ensure functional foods remain viable food sources.

There is limited clinical evidence that considers the effect of bioactive ingredients in their pure form against those incorporated within functional food products in both acute and long-term settings. Whilst there appears to be an oversupply of functional food products fortified with bioactive compounds that advertise their intention to promote health, research and regulatory scrutiny underpinning these health claims specific to each marketable food product is in short supply. Non-adherence to medications is also an increasing problem in clinical and research settings [113], with a relatively large gap in the literature concerning healthcare providers and those who consume medications regularly. There is a need to focus on functional food interventions that address behavioral strategies, especially 'habit-based' interventions such as consuming foods with added medicines or bioactive ingredients.

7. Conclusions

Functional foods are foods or beverages that claim to provide nutritional benefits beyond those found in the original food product. The development of these products can be complex, costly and require an integrated and multidisciplinary approach during all stages of development. Considering the scale of the current global functional food market, the use of sorbets as a relatively simple food matrix and carrier of active functional ingredients provides the basis for the development of several different functional food products. Furthermore, the use of sorbets can also be seen as a potential solution to some of the barriers identified with the consumption of these food products and may provide an opportunity for the easier transition of these foods into an everyday diet. In this review, we have highlighted the current opportunities, complexities and technological and health-related considerations for the use of sorbets as carriers and functional foods. This also includes the use of a variety of different ingredients (stabilizers, sweeteners, proteins) and physicochemical and organoleptic properties which allow functional foods to produce beneficial health outcomes.

Given the rise in technological advancements and innovations in food preparation and the delivery and design of new food matrices, sweeteners and different conjugates, sorbets provide an excellent opportunity for the foundation of functional food products. Sorbets should also be considered for the valorization of food waste and incorporation of underutilized and food waste ingredients. This approach can aim to implement the zero-waste food production cycles with utilizing all components of the raw food material. Furthermore, extensive research is also needed to investigate the use of these food products and health recommendations for large populations. Emphasis should be placed on functional food interventions that focus on behavioral strategies, particularly habit-based interventions such as the consumption of medications or foods containing bioactive ingredients.

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