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IMPACT OF PROBIOTICS AND PREBIOTICS ON FOOD TEXTURE

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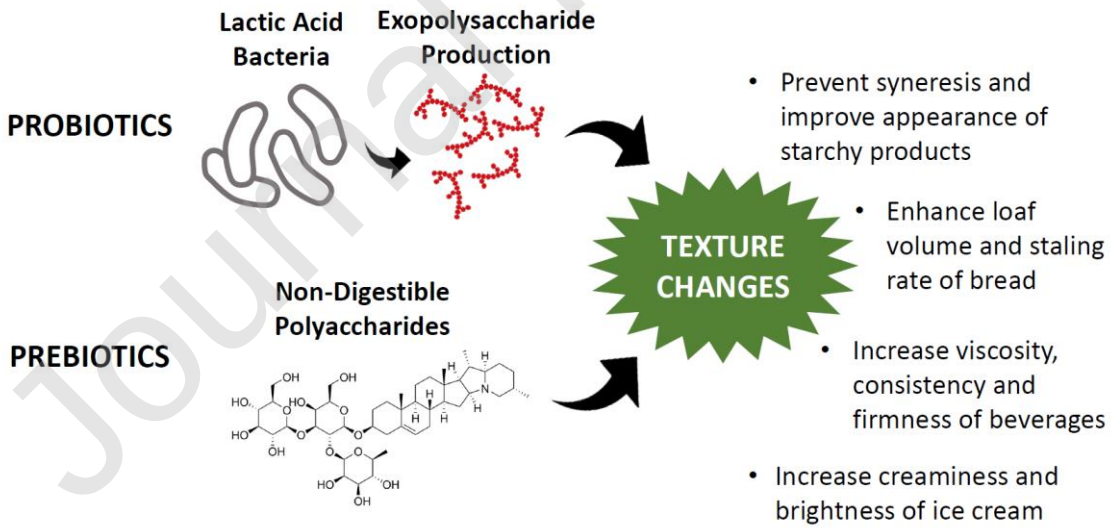
Graphical abstract



HIGHLIGHTS

- Functional food definition and health benefits were approached
- Probiotics and prebiotics are important functional ingredients with texturizing properties
- Food texture may influence the acceptance, food intake and satiety
- Inulin, FOS and GOS had the most interesting effects in viscosity, consistency and firmness
- Texture changes by probiotics are mainly related to the production of EPS by lactic acid bacteria

ABSTRACT

Functional food is the trend of the future, since our current science allows the manufacturing of processed products with health benefits beyond that of the original food, which meets the demand of the modern consumers. However, many functional ingredients may affect the products characteristics, including the texture, which is very important to the consumer's acceptance. Probiotics (Lactobacillus spp., Bifidobacterium spp., etc) and prebiotics (inulin, fructooligosaccharides, Galactooligosaccharides, etc) are widely studied functional ingredients and may change the texture of the food, improving it or not. Studies are then focusing on developing functional products with improved textural characteristics associating the healthy feature with the sensory one, thus, adding great value for these products.

Keywords: Functional ingredients; Exopolysaccharides; Dietary fibers; Sensory properties

INTRODUCTION

The feeding habits play a fundamental role in human's health. That is why so many people are concerned about their health and wellness, being the life quality a reflex of a healthy and balanced eating plus the practice of physical exercises. An alternative to a better eating is to aggregate ingredients with functional value to the daily menu. Recently, the advances in food technology allows the manufacturing of several different products, both in relation to the nutritional point of view and the sensory pleasantness. The modern consumers had been very conscious about what they are consuming, then, there is an actual demand for the manufacturing of functional products, which provide additional health benefits beyond that of the original product. However, there is another trend nowadays by consumers, which associate a product with several ingredients with unhealthy characteristics, mainly artificial additives or unknown ingredients [1]; therefore, they look for "clean label" products, with reduced number of ingredients. In this way, the food industry needs to reduce the addition of stabilizers and thickeners without compromising the food texture and taste.

The term "functional food" related to the nutritional aspect is used to describe those foods that present potential to promote health by means of non-conventional mechanisms of nutrition, being its effects restrict to the promotion of wellness and the health, maximizing the physiological functions of an individual but not the cure of a disease [2, 3*]. The production of functional foods is rising to help fighting against the health problems of the society, mainly chronic diseases, like obesity, cancer, diabetes and cardiovascular problems [4]. Currently, the main functional ingredients used in food industry are the probiotics and prebiotics, which provide many health benefits [5]; however, besides the contribution to the nutritional aspect of the products, the prebiotics and probiotics may act altering the food texture, which may be beneficial to the development of more sensorially pleasant products [6, 7].

Despite the current demand for more nutritive and functional products by the consumers, there is still an important rejection for these products due to the low sensory acceptance [8]. Therefore, the recent studies are aiming on the impact of the functional ingredients, like probiotics and prebiotics, on the food texture, in order to develop methods to improve the sensory acceptance by consumers.

FUNCTIONAL FOODS

The functional food is not a recent concept, although there is not a precise definition for it, so much that some countries does not have a definition for "functional food". These countries are based on the *Codex Alimentarius* guidelines for the use of nutrition claims to define the functional claims of its products [9*]. The most widely used definition today was established in the European Consensus and state that 'a food can be regarded as functional if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either improved stage of health and well-being and/or reduction of risk of disease' [2].

The most known and studied functional ingredients nowadays are the prebiotics and probiotics, which in accordance to literature are functional compounds with well stablished characteristics capable of providing health and wellness to the consumers, as presented in table 1.

Despite the individual health benefits of the probiotics and prebiotics, there is also a beneficial interaction between these two ingredients, which is called symbiosis, in which the combination of probiotic microorganisms and prebiotic fibers improves the effects of these compounds as well as the adaptation of the probiotic in the food product [21-23].

IMPORTANCE OF FOOD TEXTURE

The texture is one of the most important sensory characteristics of food, being critical in the perception and enjoyment of food quality, and impact directly on the consumer's mouth behavior. Therefore, texture is extremely important to product liking and preferences, also, the texture may make people reject a food or may be responsible for some kind of aversion to the food [24, 25].

It is known that the texture of food is directly related to the food intake and satiety. The texture influence the oral processing time and a long oral processing time

enhances satiation. Furthermore, the textural complexity of food, without altering the oral processing time, may also influence the satiety, since foods with complex textures stimulate many sensory perceptions during oral processing, which triggers the satiation response earlier than when chewing a less texturally complex food [26, 27*]

Furthermore, the food texture is specifically important in the development of food products for seniors, particularly those with masticatory/swallowing dysfunctions. Despite the choking risk with hard foods due to dysphagia, swallowing impairments also affect the ability to manage liquids, and aspiration is also a risk, therefore, the modification of the food texture, increasing the consistency of liquid products, is needed in these cases. Then, senior people need foods with smoother and consistent textures, because it can be easily disintegrated and mixed in the mouth and ensure safety on swallowing [28].

Despite the health benefits provided by the prebiotics and probiotics, these ingredients can influence the food texture, which may be manipulated to develop the products with the desired texture.

IMPACT OF PREBIOTICS

The most recent definition of prebiotics is “a substrate that is selectively utilized by host microorganisms conferring a health benefit” [29], than, according to this definition, the prebiotic does not need to be a carbohydrate or act specifically on the gut microbiota. Typical examples of prebiotic compounds are the oligosaccharides, which cannot be digested by human enzymes, but may be metabolized by a group of host microorganisms, mainly those from gut microbiota, as *Bifidobacterium* and *lactobacillus* [30]. Therefore, the health benefits of prebiotics are related to the stimulation of beneficial microorganisms, like probiotics, but also with the effects of produced metabolites from the hydrolysis of prebiotics, like short chain fatty acids (SCFA) [16].

Despite the known health benefits provided by prebiotics, the addition of these ingredients in food products, mainly the non-digestible polysaccharides, may change the food structure and rheological behavior. The capacity of fibers to change textural

properties are linked to the degree of polymerization/chain length, since it change the solubility of the fiber in water and the interaction with other food compounds, like proteins and other polysaccharides, which are responsible for the structural network formations [31, 32*]. Therefore, the addition of different prebiotics may change the textural properties of several food products and a summary of the applications in different products can be seen in table 2.

IMPACT OF PROBIOTICS

Probiotics are living microorganisms and when administered in adequate amounts confer health and well-being to the host [37]. In order to achieve the desired health effects, probiotic microorganism must be able to grow in the product and survive in sufficient numbers until they reach their final destination, the gut. One of the most important criteria for the selection of the probiotic bacteria is their adhesion to the intestinal mucosa and epithelial cells, this adhesion prevents the probiotic cells from being carried away by motility of the gastrointestinal tract and thus allows temporary colonization, immune modulation and competitive exclusion of pathogens [38, 39].

Probiotic microorganisms have been indicated to be present in the food at minimum concentrations of log 6 -7 CFU / g, with the daily therapeutic dose being about log 8 - 9 CFU / g [37]. Such high numbers have been suggested to compensate for the possible losses in numbers of probiotic organisms during passage through the stomach and intestines [7, 21]. Despite the health benefits of the probiotics, some strains may change the food texture, which seem to be mainly related to the production of exopolysaccharides by lactic acid bacteria (LAB) [40], however, many of these microorganisms are still not recognized as probiotics [41]. Studies that evaluated the texture changes by adding probiotics or potentially probiotic microorganisms can be seen in table 2.

Overall, the texture of food products is dependent on both the bacteria used for fermentation and process parameters and some LAB can improve texture through production of metabolites in the medium or hydrolyzing added fibers in foods during processing [42].

Polysaccharides from food-grade LAB are well known non-toxic, biodegradable and environment friendly ingredients, which act as natural thickeners, emulsifiers, stabilizers, binders, gelling agents, coagulants and suspending agents in food and cosmetics industry [46]. The EPS from LAB bacteria can also be isolated and applied to starchy products (e.g. bread, pasta, noodles, soup, salad dressings, jellies, puddings, white sauce, ketchup) in order to prevent syneresis as well as to improve appearance and texture properties of starch. Ismail and Nampoothiri [47] observed that the addition of EPS (1%) to wheat starch reduce syneresis by 50 % and increased viscosity by 28 %. Currently, the EPS are being studied due to its potential application in gluten-free bread products, since it may enhance loaf volume, shelf-life and staling rate, and textural properties of products [48**]

FINAL CONSIDERATIONS

The texture is one of the most important sensory characteristics of food products, which influence greatly the consumer's acceptance. Moreover, the texture may influence the food intake and satiety, being important in the development of products aiming to control obesity and for seniors with masticatory/swallowing dysfunctions. Despite the health benefits provided by the most studied functional ingredients (prebiotics and probiotics) nowadays, these ingredients can influence the food texture, which may worse the product's acceptance or improve the textural properties.

The prebiotics that may affect food texture are mainly fibers, which can change the food structure and rheological behavior by interacting with proteins and other polysaccharides forming strong structural networks, then, the impact of these compounds in texture depends on the type of prebiotic used and the interactions with the food matrix. Among the studied prebiotic compounds, the inulin, FOS and GOS had the most interesting effects in viscosity, consistency and firmness, mainly in liquid or semi solid dairy products. However, the addition prebiotics to solid products may influence negatively, depending on the desired texture of the product.

In relation to probiotics, the addition of these functional ingredients usually does not change the product's texture; however, some strains may grow in the food matrix

producing metabolites, which interact with the food improving the texturing properties [49*]. The changes in texture observed by adding probiotics seem to be mainly related to the production of exopolysaccharides (EPS) by lactic acid bacteria (LAB) and the perceived texture depends on the LAB strain and the types of produced EPS. The encapsulation of the probiotic may also affect the food texture. However, many of the EPS-producing LAB are still not recognized as probiotic microorganisms being necessary further studies.

In this sense, prebiotics and probiotics could be of great interest for enhance and manipulate the texture of food products, because of both functional and technological features. Thus, creating opportunities for development of novel functional foods with desirable sensory characteristics, being acceptable by consumers, besides the possibility for development of healthy products for people with dietary limitations, as the obese, the diabetics, the elderly and the celiac.

Declarations of interest: none

DECLARATION OF INTEREST

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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Table 1. Types of functional components (prebiotics and probiotics) and associated health benefits.

Type of functional components	Functional claim	References
Probiotics **Bifidobacterium spp.** **Lactobacillus spp.** **Bacillus subtillis** **Bacillus clausii** **Pediococcus acidilactici** **Streptococcus thermophilus**	"May provide beneficial effects for the reduction of gastrointestinal disease symptoms" "Exert different immunomodulatory activity" "May support heart health through blood pressure- and heart rate-lowering effects" "May help to prevent carcinogenesis" "May improve depression symptoms."	[10-14]
Prebiotics **Polyols (lactulose, xylitol, mannitol, lactiol)** **Oligosaccharides (FOS, GOS, XOS, isomaltulose, inulin)** **Other fibers (cellulose, dextrins, pectins, β-glucans)**	"May Improve intestinal health upon specific stimulatory modulation of microbiota" "May be able to counteract several metabolic disorders linked to obesity, like hyperglycemia, inflammation and hepatic steatosis" "May modulate the gut endocrine function, affecting satiety" "May act in the prevention of colonic cancer risk"	[15-20*]

Table 2. Impact of prebiotic ingredients in texture of food products

Food Product	Studied Prebiotic	Main effects	References
Whey beverage	Inulin	- The inulin had a great effect on physical stability of the beverage. - Inulin influenced the rheological parameters of the whey beverage, with increased viscosity effects, similar to that observed using gellan gum. - Overall, the use of inulin of higher degree of polymerization (inulin HP) formed stronger gel network due to the incomplete dissolution and formation of greater inulin crystals, which improved the beverage kinetic stability.	[32*]
Greek Yogurt	Inulin FOS GOS XOS Polydextrose	- The effects of prebiotics on the Greek yogurt rheology was dependent on the type of prebiotic used. - The addition of FOS provided a negative impact on the rheological parameters, conferring less consistency, elasticity, viscosity, and firmness to the products. - The addition of GOS, polydextrose, and inulin resulted in more consistent, elastic, viscous and firm products. - The highest consistency parameters observed in the yogurt supplemented with GOS are related to the formation of stronger protein network.	[33]
Ovine milk yogurt	Inulin	- The addition of inulin (2 and 6%) influenced the apparent viscosity and firmness determined by instrumental analysis and influenced the consistency in sensory analysis. - Treatment with 6% of inulin demonstrated better results in relation to the sensory preference by consumers.	[34]
Sheep milk ice cream	Inulin FOS GOS SC-FOS resistant starch soluble corn fiber polydextrose	- The ice cream added with inulin and FOS provided the highest viscosity and consistency values, which was attributed to the hygroscopic property of these fibers, forming intense water-protein interactions and a gel-like network. - However, Inulin, FOS and GOS did not change the ice cream hardness in comparison to control (10% fat) ice cream. - Meanwhile, addition of other fibers like SC-FOS, resistant starch, soluble corn fiber and polydextrose presented similar viscosities to the control ice cream but were much less harder than control and inulin, FOS and GOS ice creams. - In sensory evaluation, the ice cream containing inulin and FOS received more citations for creaminess and brightness, respectively, which are related to overall acceptability of ice cream products.	[6]
Cookie	Inulin Hydroxypropyl methylcellulose	- inulin and hydroxypropyl methylcellulose (HPMC) biscuits were harder and the sound emissions were higher than for the control biscuits. - The trained sensory panel rated the biscuit with 15 % fat replacement by inulin as crisper than the control. -The consumer study revealed that fat replacement up to 15 g/100 g with inulin or HPMC provided acceptable biscuits, but higher replacement decreased the overall acceptability. - The harder and crispier texture of the prebiotic cookies were related to the lower content of fat and lower moisture, since fat surrounds and isolates the gluten and starch, breaking the protein-	[35]

		starch continuity; as a result, higher fat biscuits are shorter, less hard and more inclined to melt in the mouth.	
Bread	Inulin/FOS	- The effects of inulin/FOS on the textural and sensory properties depended on the type of prebiotic added; flour type; substitution level; the degree of polymerization - The addition FOS may increase the crumb moistures of breads, while the addition of inulin may decrease the water absorption. -Addition of inulin to bread generally resulted in smaller loaves with a harder crumb and darker colour. - In sensory tests, the hedonic ratings tended to decrease with increasing inulin/FOS contents, however, low concentration of prebiotics appear to be sensorially similar to the standard breads.	[36]

Table 3. Impact of probiotic microorganisms in texture of food products

Food Product	Studied Probiotic	Main effects	References
Ice cream	*Lactobacillus casei 01*	- *L. casei* 01 maintained viable at a minimum therapeutic level (> 6 log CFU/mL) during the storage (5 months) - The ice cream produced with *L. casei* probiotic had lower fat destabilization and a great increase in apparent viscosity, however, the melting time was reduced.	[7]
Panela cheese	*Lactobacillus rhamnosus GG Bifidobacterium breve*	- Cheeses produced with *L. rhamnosus GG* showed greater consumer acceptance in relation to the compactness, hardness, moisture, and softness of the product, suggesting that this probiotic had an important influence on the cheese texture.	[42]
Cream cheese	*Lactobacillus rhamnosus*	- The addition of encapsulated or non-encapsulated probiotic influenced the firmness of the cream cheese - Cream cheese containing encapsulated probiotic was significantly firmer ($p < 0.05$) than its counterpart. - 1 day after manufacturing the non-encapsulated probiotic induced a softer texture, while encapsulated remained unchanged. After 21 days of storage, the difference in firmness of the non-encapsulated probiotic tended to reduce, while the encapsulated one tended to increase. - The increase in the firmness of probiotic cream cheese during storage was attributed to the acid development and proteolysis activity.	[43]
Orange juice	*Lactobacillus casei 01*	- The addition of the sodium alginate-encapsulated probiotic culture resulted in more consistent products (higher consistency index and lower flow behavior index), however, the acceptance of this product was reduced.	[44]
Carrot puree	Exopolysaccharide producing lactic acid bacteria	- Perceived texture was linked with the types of produced EPS. - The fermentation with Different bacteria was able to change the product texture, being that the *Leuconostoc lactis* and *Weissella confusa* produced the thickest textures and pleasant taste and odor. However, these bacteria are still not recognized as probiotic microorganisms.	[45]