

# Sensory Analysis: Relevance for Prebiotic, Probiotic, and Synbiotic Product Development

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**Abstract:** Sensory analysis represents a decisive step during the various stages of food product development. For probiotic, prebiotic, and synbiotic foods, which have shown continuous and significant consumption in the functional food category, the choice of an appropriate technique allows obtaining relevant sensory information that contributes to consumer acceptance. This review focuses on the importance of sensory analytical techniques in prebiotic and probiotic food product development. Examples of the most known sensory methodologies applied to these important functional foods are presented, as well as some considerations about consumer attitudes that can influence acceptance of these products. Moreover, applications of such techniques on functional product evaluation are provided.

## Introduction

Sensory analysis appeared in the mid 19th century with the so-called “taste-tests” and at the end of the 1960s started to acquire greater importance with psychophysics, a branch of psychology that studies the relationship between physical stimuli and sensory perception, as its foundation (Moskowitz and Hartmann 2009).

Currently, sensory analysis is considered as a multidisciplinary science structured on scientific principles related to the different areas of knowledge, such as food science, psychology, human physiology, statistics, sociology, psychology, and knowledge about product preparation practices, with the aim of obtaining objective responses in relation to foods with respect to the way in which they are perceived by human beings via their sense organs: visual, olfactory, taste, touch, and even auditory (Stone and Sidel 2004). It is a strategic analytical structure for professionals in the food industry, due to the constant mutation of the needs of current consumers at the moment of acquisition of a selected food and, principally, in the maintenance of this habit. Thus, modern processed food development practices obligatorily require a clear understanding of the sensory aspects and, simultaneously, an adequate choice of the techniques to be used, especially in relation to specific test methods, experimental design, and the reliability and validity of evaluations (Tuorila and Monteleone 2009).

From a sensory evaluation perspective, the 2 issues of reliability and validity are of great importance and are integral to developing a credible program and providing actionable recommendations within the context of a company's business and brand strategy.

Sensory evaluation also involves the analysis and the interpretation of the responses by the sensory professional, that is, that individual who provides the connection between the internal world of technology and product development and the external world of the marketplace. This connection is essential such that the processing and development specialists can anticipate the impact of product changes in the marketplace. Similarly, the marketing and brand specialists must be confident that the sensory properties are consistent with the intended target and with the communication delivered to that market through advertising.

If a product fails to appeal to consumers as a result of any of its sensory characteristics, it will not subsequently be acquired, and for this reason the development of methodologies capable of identifying the sensory requirements of consumers is a growing area (Kemp 2008). The commercial success of a food on the consumer market necessarily implies that it has sensory characteristics well accepted by the consumer market, safety characteristics for consumption, and nutritional qualities. In this context, in order for food control and quality assurance programs to be complete, it is absolutely essential to carry out affective tests with consumers who represent the target public or who are potential consumers of the product.

Although analytical tests are of extreme importance, they may be inefficient in detecting the presence of certain chemical compounds that may be responsible for disagreeable (or not) off-flavors with a low gustatory and olfactory detection threshold, as, for example, disagreeable flavors or tastes that can be transferred from a plastic container to the beverage contained in it, as a consequence of inadequate storage conditions with respect to temperature. Thus, the application of specific sensory tests is

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totally indispensable, be they discriminative, analytical, or affective, according to the objective (Bolini and others 2004).

Different studies described in the scientific literature have reported the application of sensory analysis with different objectives, in the search for information that could contribute effectively to generate new knowledge and provide the foundations for obtaining better food products. In the development of products supplemented with probiotic cultures or prebiotic ingredients, such information has become crucial.

In this context, this review focuses on the importance of the sensory analysis techniques to prebiotic and probiotic food development. Examples of the most known sensory tests applied to these important groups of functional foods are presented. We believe the information contained in this paper will be useful for the scientific academic community and also for food processors. Although certain alternative sensory techniques such as the open-ended question (Ares and others 2010a), free-listening (Hough and Ferraris 2010), Check-all-that-apply-CATA approach (Ares and others 2010b), sorting (Deegan and others 2010), Quantitative Descriptive Analysis-QDA (Drake and others 2009), Multivariate Adaptive Regression Splines-MARS (Xiong and Meullenet 2004), and survival analysis methodology (Hough and others 2003) have been published, representative studies covering prebiotic, probiotic, and synbiotic foods are scarce. Therefore, others will not be reported in this paper. The authors believe that a good knowledge and an adequate application of the classical sensory techniques are enough to help food processors to produce functional foods—in particular, probiotic, prebiotic, and synbiotic foods—with excellent sensory quality.

### Probiotic, Prebiotic, and Synbiotic Foods

Functional foods are products that have been enriched with added nutrients or other substances that are considered to provide health benefits over and above their nutritional value. This term covers a broad range of products: typical examples are probiotic yogurts, cholesterol-lowering spreads, and oligosaccharide-added foods (Williamson 2009).

Throughout the world, probiotics and prebiotics are leaders in sales in the functional foods category. Prebiotics are nonviable food components that exert a benefit on the health of the host, associated with modulation of the intestinal flora (FAO/WHO 2007). On the other hand, probiotics are live microorganisms, administered in quantities adequate to confer health benefits (FAO/WHO 2001). Synbiotics may be defined as the combination of probiotics (the live bacteria) and the prebiotics (the food components they live on), being mainly used because a true probiotic, without its prebiotic food source does not survive well in the digestive system (Panesar and others 2009).

According to Morais and Jacobs (2006), prebiotics, probiotics, and synbiotics will be the motive of many studies in years to come. The wide range of preventative and therapeutic possibilities is, on one hand, a motive for great enthusiasm, but, on the other hand, the principle that probably exists for each desired effect on the specificity of a determined group of effective agents, should be emphasized. In other words, the prescription of any probiotic or prebiotic does not guarantee that it will cause favorable effects on all aspects of human health. Therefore, it is possible that the current definition of probiotics should be more comprehensive in the sense that there should be a choice of a probiotic for each clinical situation of prevention or treatment. Therefore, claims of efficacy should be specific and should be made only for products

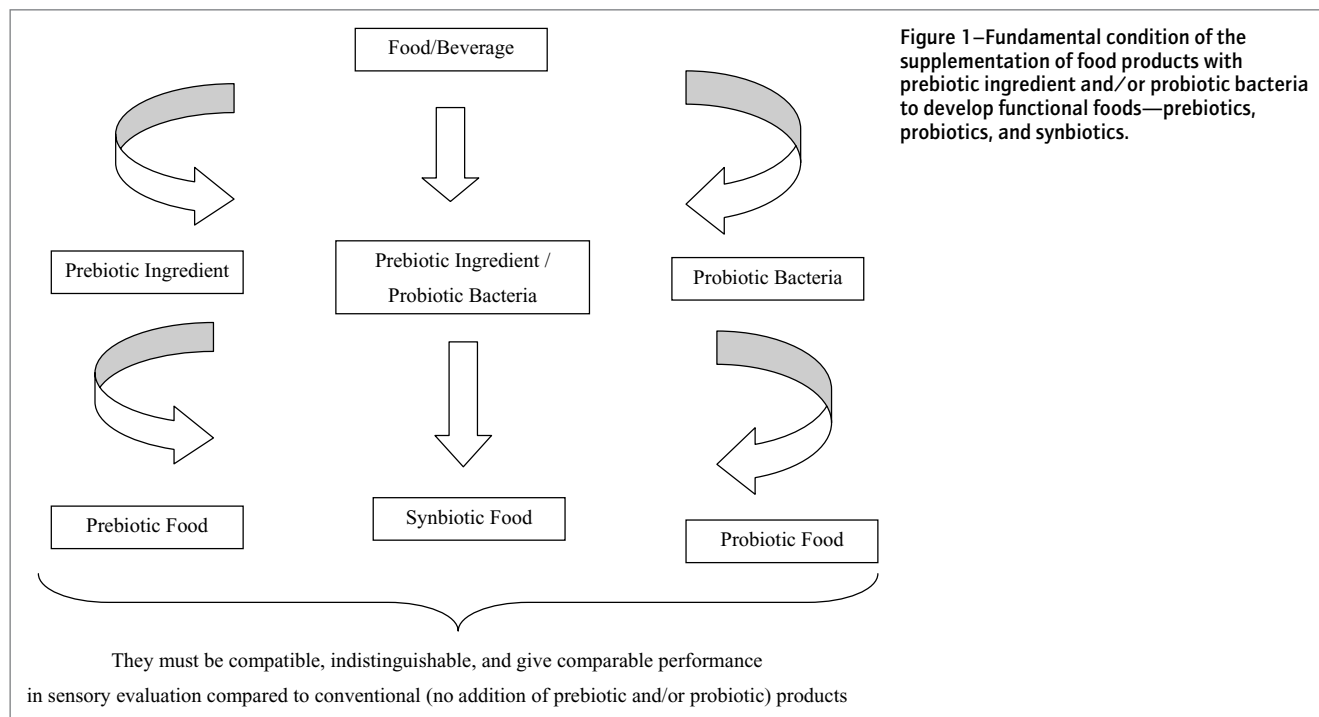
that have been found to be efficacious in carefully designed studies (Sanders 2009).

The bacteria traditionally used in yogurt production (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*) are known as lactic acid bacteria because of their capacity to use lactose as their energy substrate and to produce lactic acid. These cultures do not resist the adverse conditions of the intestinal tract, since they are sensitive to an acidic stomach and intestinal bile salts (Del Campo and others 2005) and are incapable of colonizing the human intestine. To the contrary, probiotic bacteria provide therapeutic effects by fixing themselves to the colon wall, but for this purpose they must remain viable in the food during its shelf life period and be frequently ingested (Schrezenmeir and De Verse 2001). Most probiotic species belong to the genera *Lactobacillus* and *Bifidobacterium*, the main ones used are *L. acidophilus*, *L. casei*, *B. bifidum*, *B. infantis*, and *B. longum* (Nagpal and others 2007).

Nondigestible oligosaccharides are the most studied of the prebiotics, and of all the nondigestible oligosaccharides, the following have been demonstrated to be prebiotic: lactulose, galactooligosaccharides, soybean oligosaccharides (raffinose and stachyose), isomaltooligosaccharides, glucooligosaccharides, and xylooligosaccharides (Martínez-Villaluenga and others 2006). Nevertheless, oligosaccharides such as inulin, oligofructose, and resistant starch are the main types of prebiotic used in foods (Sajilata and others 2006; Waligora-Dupriet and others 2006), although there is an increasing demand for galacto-oligosaccharides in food products due to their health-related effects (MacFarlane and others 2007).

The benefits of consuming foods containing probiotic cultures and prebiotic ingredients have been demonstrated in many scientific fields (Hamburger and others 1997; Sanders 1998; Sanders and Klaenhammer 2001). Studies involving the ingestion of products containing some specific cultures have resulted in a reduction in lactose intolerance, increase in activity of the immunological system, antimicrobial activity, anticarcinogenic and antimutagenic activity, reduction in blood cholesterol level, overcoming of the gastric ulcerative infection caused by *Helicobacter pylori*, and in the treatment of the nervous intestine syndrome (Shah 2007; Agrawal 2009; Fung and others 2009). Diverse benefits have equally been reported and clinically proven for the ingestion of foods with added prebiotics including the following: improved mineral absorption, especially that of calcium, resulting in strengthening of the bone mass and prevention/retardation of osteoporosis (Bosscher and others 2006), reduction in the risk of certain infirmities such as diarrhea associated with intestinal infections, reduction in cholesterol levels due to a positive influence on lipid metabolism and modulators of the immunological system (Renhe and others 2008) and obesity/insulin resistance (Delzenne and Cani 2010).

Articles in the scientific literature have been published that cover probiotics and prebiotics in food processing are available as general reviews (Champagne and others 2005) and for specific food matrices as yogurt and fermented milk (Lourens-Hattingh and Viljoen 2001; Sanchez and others 2009), cheese (Cruz and others 2009a), icecream (Cruz and others 2009b), functional beverages, including probiotic ones (Ozer and others 2009), meat products (De Vuyst and others 2008), cereal products (Lamsal and Faubion 2009), and nonprobiotic dairy beverages and food products (Prado and others 2008; Granato and others 2010a; Rivera-Espinoza and Gallardo-Navarro 2010). Reviews about specific topics involved in probiotic and prebiotic food processing, like packaging systems (Cruz and others 2007), relevance of probiotic food carrier



(Ranadheera and others 2010), several hurdles faced by probiotic bacteria along the food product manufacture (Corcoran and others 2008), microencapsulation (Mortazavian and others 2007), and oxygen toxicity (Talwalkar and Kailasapathy 2004) are also available, as well as prebiotic science and technology (Wang 2009; Cruz and others 2010). To the best of the authors' knowledge, this is the 1st review dedicated to sensory techniques applied to probiotic foods.

Throughout the world, the consumption of probiotic foods has increased considerably in recent years. In Europe this sector amounts to a total of €1.4 billion, led mainly by yogurts and desserts, which account for approximately 72% of this total (Saxelin 2008). In fact, fermented milks are the main vehicle for the incorporation of probiotic cultures or prebiotic ingredients, although from a technological point of view, cheeses and icecreams also show advantages in relation to this type of product (Cruz and others 2009a, 2009b).

Prebiotic foods are classified in the category of functional foods and represent a significant part of this market. In fact, the 180 new food products launched onto the market in 2006 demonstrate the status of prebiotics (Sveje 2007). Recent data suggest that world demand for prebiotics is estimated at 167,000 metric tons, generating €390 millions (Siró and others 2008).

### Application of sensory tests to probiotic and prebiotic product development

In a first and general view, prebiotic, probiotic, and synbiotic foods must show, at least, the same performance in any sensory test (Figure 1). Overall, research exclusively directed at comparing and/or applying sensory methodologies to the development of probiotic and prebiotic foods does not predominate. In the majority of cases only affective tests are carried out, aiming to determine acceptance of the product, without, however, obtaining greater detail concerning the addition of the probiotics and prebiotics to the product and their interaction with the consumer. It is thus indispensable that the development of prebiotic, probiotic,

and/or synbiotic products be accompanied by specific sensory analyses to allow for the acquisition of the best conditions and of real knowledge in the search for products well accepted on the consumer market, be they of animal or vegetable origin (Figure 2f). Some studies have reported the possibility of obtaining similar, or even better, performance with probiotic or prebiotic products as compared to conventional products: this was shown for low-fat salami sausage with added inulin (Mendonza and others 2001), functional yogurt supplemented with *L. reuteri* RC-14 and *L. rhamnosus* GR-1 (Hekmat and Reid 2006), coconut pudding with added *L. paracasei* and *B. lactis* (Correa and others 2008), chocolate mousse with added inulin and *L. paracasei* (Aragon-Alegro and others 2007), fresh Minas-type cheese made with cow milk (Souza and others 2007) and with buffalo milk (Marcatti and others 2009) supplemented with *L. acidophilus*, grape juice with inulin, and *L. acidophilus* (Santos and others 2008), chocolate and lemon-flavored muffins supplemented with tagatose (Armstrong and others 2009), banana yogurt supplemented with *L. acidophilus* and *Bifidobacterium* spp. (Bakirci and Kavaz 2008), milk fermented with *B. animalis* and *L. acidophilus* La-5, and supplemented with inulin (Oliveira and Jurkiewicz 2009), and corn-snacks manufactured with fructans-based fat replacer enriched with inulin and oligofructose (Capriles and others 2009).

An adequate application of sensory methodology allows one to obtain important results on the formulated food, providing prior knowledge with respect to its acceptance on the consumer market and/or specific characteristics or a descriptive sensory profile, serving as the foundation for making alterations or otherwise, as required. Whenever possible, in the majority of cases it is important to analyze similar commercial products in parallel, for comparative reasons. In general, substitution with prebiotic ingredients has a greater influence on texture and aroma, whereas substitution with probiotic products has a greater effect on flavor and aroma. In the 1st case, the prebiotic ingredient is incorporated into the product matrix, conferring, and enforcing already existent bonding between different components of

Sensory test		Application for prebiotic, probiotic and synbiotic foods
Discriminative	Duo-Trio, Triangular, Difference from control	<ul style="list-style-type: none"> <li>✓ Limited information;</li> <li>✓ Just indicated if there is a difference between prob/preb/synb product towards the conventional one;</li> <li>✓ It should be performed at different times of the shelf life to have better idea about the functional food performed;</li> </ul>
Affective	Focus group Preference, Acceptance	<ul style="list-style-type: none"> <li>✓ Evaluate the knowledge and understanding in consumers about the functional products, helping to elaborate adequate marketing strategies;</li> <li>✓ Allows knowing the consumer's evaluation of the product in a quantitative way, checking its performance against commercial and conventional ones;</li> <li>✓ It needs an excessive number of consumers in addition to knowledge of chemometric tools (PCA, HCA) to achieve improved and reliable results;</li> </ul>
Descriptive	QDA, FC, TIA	<ul style="list-style-type: none"> <li>✓ Develops the sensory profile of the product, helping to identify all the sensory features of functional products, their negative and positive points compared to conventional and commercial ones in a static and dynamic form;</li> <li>✓ Allows the improvement of a functional food formulation: exchange of ingredients, increase / decrease in the amount of prebiotics and probiotics</li> <li>✓ Global evaluation is obtained when performed at different times of the functional food during its shelf life.</li> </ul>

Figure 2—Application of sensory test on the development of probiotic, prebiotic, and synbiotic foods.

the food and frequently substituting the fat, which is directly responsible for the softness and creaminess of the food when ingested. In the 2nd case, metabolism of the probiotic culture can result in the production of components that may contribute negatively to the aroma and taste of the product—the so-called probiotic off-flavor. One must also remember that the *Bifidobacterium* spp. produce acetic acid as a product of their metabolism, which can result in a vinegary flavor in the product, prejudicing the performance in sensory assessments (Tamime and others 1995).

It must be emphasized that the technological options available for the development of these products such as microencapsulation (Talwalkar and Kailasapathy 2003) and an increase in inoculum of the probiotic culture (Olson and Aryana 2008) attempt only to solve the question of protecting the probiotic strain such that it survives in a viable form throughout the shelf life of the product, and during its passage through the intestinal tract, in amounts sufficient to confer clinical benefit to the host. This can sometimes prejudice the sensory performance of the product by causing alterations in the flavor and texture of the product during storage (Khorokhavar and Mortazavia 2010). However, it has been equally shown to be possible to use this technology without detriment or decrease in the performance of the product in consumer tests (Kailasapathy 2006; Homayouni and others 2008; Ozer and others 2008, 2009).

### Discriminative tests

Discriminative tests can be used for several objectives. In some cases one is interested in demonstrating if 2 samples are perceptibly different; in other applications, one wishes to determine if the samples are sufficiently similar to be used unequivocally; and, finally, in a 3rd type of application, the finality is to quantify the degree of similarity to or difference from the principle that it is recognized in the product. As examples of this type of sensory

test one can cite the triangular test, the paired-comparison test, the duo-trio test (for comparison of 2 samples), and the difference from control test (Meilgaard and others 2004) for comparison between more than 2 samples. It is important to keep in mind that the sole purpose of these tests is to determine if a difference exists. Difference tests are probably the most commonly misused sensory tools because the nature of the difference, the degree of difference (except difference from control), and consumer preference cannot be determined using this test, nor can these questions be asked of panelists when taking a difference test. Performing these tests require generally 25 to 50 panelists (Drake 2008).

In the development of prebiotic and probiotic products, discriminative tests can represent an alternative to check if supplementation of the food with a probiotic strain or prebiotic ingredient is perceived when evaluated simultaneously with the conventional product, throughout the storage period or at specific moments during this period. However, they are not able to give more detailed information about particular sensory attributes of the product, which prevents detecting strengths and weaknesses of the product at the consumer's point.

Discriminative tests have been applied with success in the development of a frozen synbiotic cabbage palm fruit dessert (Vasconcelos and others 2009); evaluation of probiotic Pategras cheese ripening (Perotti and others 2009), probiotic acai pulp yogurt (Almeida and others 2009); probiotic cabbage palm fruit dairy beverage (Zoellner and others 2009); synbiotic chocolate mousse (Aragon-Alegro and others 2007); whey dairy beverage containing acai pulp supplemented with *L. acidophilus* and *B. longum* (Zoellner and others 2009); fresh Minas-type cheese supplemented with *L. acidophilus* (Buriti and others 2008) or by coculturing with a thermophilic starter (Souza and others 2007); synbiotic fresh cream cheese with inulin and *L. paracasei* (Buriti and others 2008); fermented milk containing microencapsulated *L. acidophilus* LA-5



and *B. lactis* BB-12 (Khorokhavar and Mortazavian 2010), and an edible biospread supplemented with potentially probiotic *Lactobacillus* and *Bifidobacterium* species (Charteris and others 2002).

Interesting findings are reported by Heenan and others (2004) and Bergamini and others (2009). In the former research, probiotic microorganisms were incorporated into a nonfermented, vegetarian frozen soy dessert and the product was assessed for the survival of probiotics viability (*L. acidophilus* MJLA1 and *S. boulardii* 74012) and sensory acceptability during 7 mo of storage. The triangle test was performed for a comparative sensory analysis. For each test, 3 samples were presented to panelists (18 to 30 panelists). Panelists indicated which of the 3 samples was different from the other 2 and which of the samples, pair or single, was preferred. The data were analyzed using *t*-tests. Responses from panelists who correctly answered the triangle test were used to calculate the sample preference *t*-test. The product inoculated with *L. acidophilus* could not be distinguished from the control sample. On the contrary, the product with *S. boulardii* obtained low sensory acceptability and differed from the control and from that with *L. acidophilus*. In the 2nd one, several strains of probiotic bacteria—3 of *Lactobacillus acidophilus* and 3 of *Lactobacillus casei*—were added to the semihard Argentinean cheese during its processing. A difference from control test was applied right after 60 d of ripening, using 20 panelists who assessed the following attributes: intensity of flavor, acid taste, and global texture. Differences were observed for probiotic cheeses and control cheese, with the probiotic cheeses having higher scores for the sensory attributes. These results were also confirmed using multivariate techniques such as hierarchical cluster analysis and principal component analysis. This is related to probiotic culture metabolism, suggesting the need of a preliminary test with the cultures which will be added into the food matrix.

In fact, the simple decision of supplementing a food with probiotics or prebiotics is not enough. Information about their impact on sensory properties should be evaluated, once the change can be either positive or negative on the consumer's mind. A continuous dialog with suppliers shall be kept to obtain more consistent information, which is essential for small and medium-sized companies.

### Affective tests

Affective sensory tests are included in the quality control of foods, since they are the only way of knowing whether consumers like the product or not and to what extent. Such tests are indispensable for foods supplemented with probiotic cultures or prebiotic ingredients, since these show great potential for commercialization. These tests are very easy to perform once potential consumers can be used in all the steps of the food development. In a general way, hedonic scales structured with 5, 7, or 9 points are the most widely used by food companies and also by researchers.

Furthermore, when quantitative consumer tests are conducted, their objective is to determine or infer consumer likes and dislikes. Consumers are highly variable and constantly changing due to shifts in age, advertising, new experiences, new products, and so on. For this reason, large and successful companies have extensive sensory and market research departments that conduct these tests regularly and with large numbers of representative consumers (Drake 2008). Preference and acceptance tests are the most widely known and applied consumer tests (Meilgaard and others 2004). In preference testing, consumers are presented with 2 or more samples and asked to indicate which sample they prefer. If more than 2 samples are presented, consumers can also rank their preference (preference ranking). The test is a generally forced choice; that is,

a preference must be indicated, even if the consumers do not like any sample. Thus, we do not advise the reader to use this practice in an acceptance test, although there are some peer-reviewed papers that report this practice. The correct choice of the sensory methodology to be applied in a sensory study helps the researcher to obtain reliable results.

Acceptance testing is also called degree of liking. Consumers are presented with products and asked to indicate their degree of liking on a scale. The most commonly used scale is the 9-point hedonic scale; at least 50 consumers are needed to determine preference or acceptance of a product with any degree of certainty (Drake 2008). In fact, once there is a great subjectivity in sensory evaluation, a large number of respondents in the sensory panel is necessary to obtain a suitable degree of confidence in the results (Drake 2008).

It is important to point out that some small companies may feel attempted to perform affective tests with their employees. However, this practice must be avoided in all types of companies because people who have contact with the product in its different stages of processing may not feel comfortable to state their true opinions and, hence, misleading results may be obtained. In order to avoid this situation, potential consumers, with different ages and regions, should be used in affective tests.

Another aspect that should be emphasized here is when formulations with slight modification in their ingredients need to be sensorially tested. In general, it is very difficult to make predictions as to the possible perceptible differences among products that differ in chemical composition and/or structure due to changes in the formulation. In food acceptability studies, 2 critical questions arise: how the consumers perceived the sensory characteristics of the food and how much the variation in the sensory characteristics perceived influences consumer responses (Villegas and others 2009).

Taylor and others (2008) studied the suitability of tagatose, a minimally absorbed prebiotic monosaccharide, as a replacement for sucrose at various replacing levels (ranging from 25% to 100%) in cookies. The rheological and sensory properties (color, sweetness, texture, and overall likeness) were assessed for treatments. For the sensory test, a 9-point categorical hedonic scale was used, anchored by "dislike extremely" and "like extremely." For the tagatose-containing cookies, the extent of likeness was evaluated by 53 untrained panelists using a 9-point hedonic scale. The tagatose-containing cookies were harder and darker with a lower spread than the control. Panelists liked the brown color of the 100% tagatose cookies better than the control, but disliked their sweetness. Overall likeness scores of the control and cookies made by replacing half of the sucrose with tagatose were the same. Tagatose was thus recognized as a suitable partial replacer for sucrose in cookies.

Devereux and others (2003) investigated the sensory acceptance of various food products—cookies, carrot cake, chocolate cake, icecreams, and frankfurters—with partial substitution of fat by oligofructose and inulin. Although good acceptance was observed for all the products, with no significant difference between these and the products containing no prebiotics, the scores received by the supplemented products were always slightly lower for all the attributes analyzed, and there was also a potential influence on the texture, independent of the product studied.

Madureira and others (2008) studied the sensory acceptance of a cheese whey beverage supplemented with *L. paracasei* LAFTI L26 in several versions with chocolate and sucrose, with strawberry jam, just with sucrose, with sucrose and aloe vera, and with no added flavor. The addition of sucrose into the probiotic

formulations resulted in higher sensory acceptance in relation to the control beverage. Texture was the most appreciated sensory property. As storage progressed, there was a decrease in the sensory scores until eventually the control beverage became more accepted. The authors hypothesized that the additives increased the metabolism of the probiotic strain, which may explain why the whey beverage became more acidic and, consequently, less appreciated by the taste panel.

A functional beverage formulated with fructooligosaccharide and soluble fiber was analyzed with respect to its physicochemical characteristics and acceptance (Freitas and Jackix 2004). A mixed carrot and orange nectar was formulated with added fructooligosaccharide and citric pectin. The influence of adding these functional ingredients on physicochemical characteristics and sensory acceptability was evaluated. The addition of fructooligosaccharide interacting with the added pectin increased the soluble solids content and viscosity of the beverage. The analysis of the results showed that the presence of the fructooligosaccharide did not cause a negative effect on the sensory acceptance of the beverage, even at a high concentration (15% w/w). However, the addition of citric pectin in concentrations above 1.0% w/w caused an increase in pH and the formulations were not well accepted by the judges in the sensory evaluation.

Castro and others (2008) carried out a study to evaluate the addition of fructooligosaccharide in dairy beverages. The authors analyzed the preference and acceptance of samples of fermented probiotic dairy beverages with added milk whey (30%) and fructooligosaccharide (2% and 5%), comparing with a sample without the addition of these ingredients. The samples with added whey and fructooligosaccharide were preferred ( $P \leq 0.05$ ) and showed good acceptance, demonstrating that although some physicochemical properties had been altered, the final product garnered higher acceptability scores than the traditional one. According to Almeida and others (2000), Miller and others (2000), and Penna and others (2001), the use of milk whey in dairy beverages resulted in a product highly accepted by consumers, once it was more liquid and less acidic. Good acceptance of the addition of fructooligosaccharide was also observed in yogurt samples supplemented with inulin (El-Nagar and others 2002; Kip and others 2006).

Antunes and others (2004) analyzed the influence of adding whey protein concentrate on the texture profile, whey separation, and acceptance of skimmed probiotic yogurts during storage. Acceptance was determined by 30 habitual consumers of natural yogurt, using a 9-cm nonstructured hedonic scale. The sample, chosen in an earlier experiment, once it presented instrumental texture characteristics and whey separation similar to those of whole yogurt, was submitted for evaluation together with 2 yogurts (whole yogurt and skimmed yogurt) to which only skimmed milk powder had been added. The samples were offered with added honey in a monadic way. The judges were asked to evaluate the degree of liking of appearance, flavor, texture, and overall impression and also to indicate the purchase intent of each product. The judges were able to identify that the yogurt with added whey protein concentrate differed from those without this ingredient. However, there was no significant difference in acceptability between the samples containing probiotic cultures and those that did not.

Zacarchenco and Massaguer-Rossig (2004) showed that milk fermented by *S. thermophilus* and *L. acidophilus* ( $10^8$  CFU/mL) presented a low acceptability, whereas the product fermented by *B. longum* and *L. acidophilus* in the proportions of  $10^8$  and  $10^7$  CFU/mL were more accepted by the taste panelists.

Antunes and others (2005) carried out a study to determine the influence of adding whey protein concentrate on the growth and viability of lactic nonbiotic and probiotic cultures, on the texture profile, and on whey separation during the shelf life of yogurts. They analyzed 8 samples that contained different proportions of milk protein and whey protein concentrate, all fermented by *S. thermophilus* and *L. bulgaricus*, with addition of *L. acidophilus* or *B. longum* or mixtures of these strains. The samples were submitted to sensory analysis in 2 distinct stages. The 1st consisted of the difference from control test to evaluate if the judges were capable of identifying differences between the samples due to the addition of the whey protein concentrate and the probiotic cultures. This analysis was carried out with 30 consumers of yogurt who were asked to evaluate the natural yogurts and compare them with the standard by using a 9-point hedonic scale. Subsequently, an acceptance test was carried out using 30 habitual consumers of yogurt using a nonstructured 9-point hedonic scale to verify acceptance of the probiotic yogurts with and without the addition of whey protein concentrate. Since this product would generally not be consumed in the pure form, the judges were offered the option of adding honey, sugar, sweetener, or fruit jelly, according to their regular consumption habits. The samples were presented in a monadic way. The authors concluded that there was a perceptible sensory difference ( $P < 0.05$ ) among the samples with and without the addition of the whey protein concentrate, but that there was no significant difference in acceptance of the yogurt samples as a function of the type of culture employed (presence or absence of probiotics). When the judges evaluated the yogurts under the conditions they habitually used to consume such products (with added honey, sugar, sweetener, or fruit jelly), all samples presented high acceptance scores.

Aryana and McGrew (2007) studied the effect of 3 prebiotics with different-sized chains: inulin of short, medium, and long chain lengths on the sensory acceptance of the products yogurts with added *Lactobacillus casei*. The yogurt sample with *L. casei* and no addition of inulin (control) and the sample with *L. casei* plus the shortest chain inulin presented the greatest score for flavor when compared to the samples that contained longer-chain prebiotics. With respect to texture, the sample that had long-chain inulin showed a greater viscosity ( $P < 0.05$ ) when compared to the control sample and the formulation that had oligosaccharide. These results show that inulin can be an alternative as a fat substitute in yogurts. Other studies (Niness 1999; Douglas 2005) reported that long-chain inulin was also a good fat substitute.

González-Tomás and others (2009) studied the effects of adding different-chain-length inulin (long-chain, native, and short-chain) at a concentration of 7.5% (w/w) on physicochemical and sensory characteristics of starch-based dairy desserts formulated with either skim or whole milk. Twelve assessors with previous experience were used. They were asked to fill in a check list. The initial list, composed of 21 terms regarding the appearance, odor, flavor, and texture of the samples, was finally reduced to 18 after the training sessions with the assessors. Descriptive analysis (line-scale rating test) was used for sensory assessment of the samples. For each sample, odor attributes were evaluated first, then, the assessors were asked to evaluate appearance, flavor, and texture attributes. The intensity of each attribute was scored on a nonstructured 10-cm scale, with the corresponding end terms. The effect of adding the mentioned amount of inulin of different-average chain length could give rise to products with different rheological behavior and different sensory properties. The skim milk sample with long-chain inulin and the whole milk sample

without inulin were perceived to present the same creaminess and consistency intensity, but the addition of long-chain inulin increased roughness intensity and, consequently, the sensory quality was negatively affected.

Behrens and others (2004) formulated a fermented product with water-soluble soybean extract containing 2% sucrose and inoculated with a combination of 3 microorganisms: *Streptococcus thermophilus*, *Bifidobacterium lactis*, and *Lactobacillus acidophilus*. The fermentation was monitored by measuring the pH as a function of time. These samples were used as a base for fermented beverages with the following flavors: pineapple, strawberry, coconut, kiwi, guava, and hazelnut. The beverages were evaluated by consumers using affective tests with a structured 9-point hedonic scale. The data were analyzed by 2-way ANOVA and Internal Preference Mapping, which allowed the authors to determine that the pineapple, and guava-flavored beverages were significantly ( $P < 0.05$ ) better liked. The strawberry, kiwi, and coconut beverages received mean acceptance scores close to 6 (moderately liked), whereas the hazelnut-flavored beverage was rejected (mean below 5). This study showed it is possible to develop probiotic beverages with a suitable sensory acceptability using water-soluble soybean extract.

Cardarelli and others (2007) carried out a sensory evaluation of synbiotic petit Suisse cheeses that contained viable probiotic counts, fructan, inulin, oligofructose, and honey oligosaccharides combined in different proportions. The probiotic population varied between 7.20 and 7.69 log CFU/g for *Bifidobacterium animalis* ssp. *lactis* and 6.08 to 6.99 log CFU/g for *Lactobacillus acidophilus*. The authors reported a significant ( $P < 0.05$ ) increase in acceptance during storage for the samples supplemented with oligofructose and/or inulin, but not for those that contained honey. The most accepted synbiotic petit Suisse cheese was that the one that contained a combination of oligofructose and inulin.

In studies by Favaro-Trindade and others (2006), icecream samples containing acerola pulp were formulated with the use of different starter cultures (*Bifidobacterium longum*, *B. lactis*, *Streptococcus thermophilus*, and *Lactobacillus delbrueckii* spp. *bulgaricus*). The authors analyzed the viability of the probiotic cultures, the ascorbic acid stability, and the sensory acceptance. Fermentation by the culture combinations was interrupted when pH values of 5.0 to 5.5 were reached, and the addition of acerola pulp caused a decrease in the pH value to 4.5 and 5.0, respectively. The results of this study showed the viability of the cultures remained above the recommended minimal limit of  $10^6$  CFU/g for 15 wk at the pH value of 4.5. The authors concluded that the product obtained represented a good way of consuming ascorbic acid and *Bifidobacterium* spp., with acceptable sensory properties.

Aiming to verify the effect of adding probiotic cultures to the formulation of frankfurter sausages, Muthukumarasamy and Holley (2006) analyzed the acceptance of frankfurters with added nonencapsulated *Lactobacillus reuteri*, and of frankfurters containing the same microorganism encapsulated by 2 distinct methods (extrusion and emulsion), comparing them with the control sample containing no probiotic culture. Seventy-two consumers were used in the affective analysis and all the frankfurter samples showed good acceptance, with means varying from 7.04 to 7.34, not presenting significant difference at the 5% level, showing that the addition of encapsulated cultures could be a good option for meat products. In addition, 78% of the consumers reported that the addition of probiotics to the frankfurters contributed positively to their buying intention.

Frutos and others (2008) studied the application of artichoke fiber in the manufacture of bread, with the objective of analyzing texture differences in samples with different concentrations of this fiber (0%, 3%, 6%, 9%, and 12%). An acceptance test with 50 individuals was carried out and results showed that as the fiber concentration increased the acceptance decreased. This result can be explained by hardening of the crumb caused by the addition of the fiber. The addition of 3.0% and 6.0% artichoke fiber did not affect the acceptability of the bread.

Antunes and others (2009) evaluated the sensory acceptability of a probiotic buttermilk-like fermented milk product flavored with different flavors (strawberry, vanilla, mint, *graviola*, and *cupuaçu*) and with added sucrose or sucralose. All the sucrose-added buttermilks presented the same performance in the acceptability test, with the results ranging from “like slightly” to “like moderately” which corresponds to a 6 to 8 score, on a 9-point hedonic scale. The same behavior was observed for sucralose-added samples.

Villegas and others (2009) used response surface methodology to optimize the acceptability of prebiotic low-fat beverage formulations containing different types of inulin: the former with a high level of short-chain molecules (2 to 10 monomers) and the 2nd with long-chain length ( $> 23$  monomers). Two separate groups of beverages, one for each type of inulin was prepared with different levels of sucrose and inulin. Differences in acceptability were mainly attributed to the formulation and also to the inulin type. Samples with added short-chain inulin presented more acceptability scores toward the long-chain inulin, although, overall, no statistical significance was noted. Inulin concentration was responsible for explaining variations in acceptability data, and consumers perceived remarkably the sensory differences among samples.

Sanz and others (2009) investigated the effect of 4 different resistant starches (RS) on the acceptability of muffins. Two samples—different RS type 2 samples (Hi-Maize 260 and Novelose 240)—presented similar scores for appearance, texture, taste, and overall acceptance in relation to the control. The former was scored the highest for all the sensory attributes, ranged from 6 (slightly liked) from 7 (moderately liked) in the 9-point hedonic scale. By using principal components analysis, the authors verified that there was a positive correlation between the springiness and sensory attributes.

Desserts made with soy cream, which are oil-in-water emulsions, are widely consumed by lactose-intolerant individuals in Brazil. In this regard, Granato and others (2010b) aimed at using response surface methodology (RSM) to optimize the sensory properties of a soy-based emulsion supplemented with oligofructose over a range of pink guava juice (GJ: 22% to 32%) and soy protein (SP: 1% to 3%). Water holding capacity and backscattering were also analyzed after 72 h of storage at 7 °C. Furthermore, a rating test was performed to determine the degree of liking of color, taste, creaminess, appearance, and overall acceptability using a 7-point hedonic scale (1 = “strongly disliked”; 2 = “moderately disliked”; 3 = “slightly disliked”; 4 = “indifferent”; 5 = “slightly liked”; 6 = “moderately liked” and 7 = “strongly liked”). The data showed that the samples were stable against gravity and storage. The mathematical models developed by RSM adequately described the creaminess, taste, and appearance of the prebiotic emulsions by presenting an adjusted determination coefficient ( $R^2_{adj}$ ) above 70%. The response surface of the desirability function was used successfully in the optimization of the sensory properties of dairy-free emulsions, suggesting that a product with 30.35% GJ and 3% SP was the best combination of these components.

The sensory properties and overall acceptability of another dessert made with SP and yellow passion fruit juice (PFJ) supplemented with oligofructose were assessed by Granato and others (2010c). Panelists used a 7-point hedonic scale to evaluate the degree of liking of creaminess, taste, color, and overall liking of the desserts. In addition, the samples were submitted to a ranking test in order to evaluate the preference. Samples made with 25% PFJ and 3% SP, 35% PFJ and 3% SP, and 30% PFJ and 2.5% SP presented mean hedonic scores above “slightly liked” for all the sensory attributes. The acceptance index of samples, which was calculated by the percentage of respondents who indicated that they “slightly liked,” “moderately liked,” or “strongly liked” the product, varied from 62.50 to 88%, showing a great sensory potential of prebiotic nondairy desserts.

### Descriptive tests

Descriptive tests are among the most sophisticated tools for sensory analysis in comparison with discriminative tests. The results from a descriptive analysis test provide complete descriptions of a product, provide the basis for mapping product similarities and differences, and provide a basis for determining those sensory attributes that are important to acceptance. This would be a qualitative and quantitative method performed by a team of 12 to 15 rigorously selected and trained judges (panel) and a panel leader (Mialon and Murray 2001).

The Quantitative Descriptive Analysis (QDA)—the descriptive method published by Stone and others (1974), Tragon’s method—Free Choice Profile (FCP), and Time-Intensity Analysis (TIA) are among the descriptive sensory tests most often used in scientific studies and by the food companies. QDA and FCP have the same purpose, that is, to determine the intensities of all descriptors in a product, and to determine the complete sensory profile, while the TIA has the purpose of determining the intensity of a unique descriptor with time and provide the intensity and the time of duration of any descriptor term in a product (Bolini and others 2003).

Among these methods, the QDA is the most frequently used methodology and consists of a sequential survey of sensory terms for a product generated by a trained sensory panel using nontechnical language and supervised by a leader, who should not be an active participant in the process. The success of the method implies that there is a consensus between the trained judges in relation to the relative differences between the samples, which are the source of information (Murray and others 2002).

In FCP, there is no prior training of the judges, each judge announcing his/her own list of attributes to designate the product, resulting in a reduction in the time spent on the analysis when compared with QDA; and it is a methodology that is easy to apply (Oliveira and Benassi 2003). However, the statistical analysis of the data is much more elaborate, available only from a few statistical software packs, a common method used to analyze FCP data being the Generalized Procrustes Analysis (GPA) (Dijksterhuis 1995).

In TIA the objective is to evaluate the change in intensity of a determined attribute with time, as, for example, bitterness or sweetness. The judge should invariably be trained and the response is recorded by a computerized system. As a result, a time-intensity curve is obtained for the determined attribute, which is a graphical representation of the attribute recorded with respect to the time of analysis (Bolini and others 1996). From this graph, 3 parameters can be obtained: the maximum intensity ( $I_{max}$ ), the point at which  $I_{max}$  is reached ( $t_{max}$ ), and the first point of no more perception occurring; these 3 can be examined by analysis of variance for

assessor and sample effects (Dijksterhuis and Piggott 2001). Although this methodology has been applied with success in various foods, such as strawberry jam (Alves and others 2008), chocolates supplemented with sweeteners (De Mello and others 2007), and dietetic jellies (Palazzo and Bolini 2009), not even one report has been found in probiotic and prebiotic foods due to the need for panel training and the use of specific software.

Information on the use of descriptive techniques for probiotic, and prebiotic products in particular, is still scarce and limited to only a few studies. It is important that the application of such techniques in these types of product includes similar commercial products or prototypes containing no probiotic cultures or prebiotic ingredients, in order to compare the attributes used and to identify particular items where improvements can be made in the formulation, in order to approximate the 2 types of product.

Many small and/or medium-sized probiotic/prebiotic food companies, for economic reasons, choose to perform acceptance tests of their products by using a small group of people who had some form of training. It is crucial to remember that at trained panel must not measure liking, acceptance, or preference. Once panelists are trained to identify and quantify attributes in products (or grades and defects such as with product judging), they are no longer typical consumers. As such, what they like or prefer generally is no longer relevant or comparable to those of the average consumer (Drake 2008). Unfortunately, even in peer-viewed publications, it is not rare to observe researchers using these types of assessors, which demonstrates the lack of attention to the principles of sensory analysis.

Indeed, it is important to have a specialized professional within the company in order to have proper and effective implementation of various existing methods in sensory analysis, which are observed to avoid erroneous results that may jeopardize the success of the product during its marketing. Drake (2008) reported that the largest and most successful food (and nonfood) companies have large sensory and market research divisions or make use of sensory consulting firms. In this context, much attention is given to appropriate selection of sensory tests and appropriate use of the selected tests.

A combination of statistics methodologies can be used in order to extract the maximum amount of information concerning the sensory attributes of a probiotic, prebiotic, and/or symbiotic product and its behavior throughout its shelf life. The most representative sensory descriptor terms are in QDA—obtained using multivariate statistical analysis such as the Principal Component Analysis—can be submitted to the TIA method at different points during storage of the product. This can give an indication of the positive or negative impact of the probiotic culture and/or the prebiotic ingredient in the food matrix and provide inferences concerning its viability in the food product.

It is also noteworthy that a few researchers have paid attention to the application of right and accurate statistical techniques on sensory data, especially the ones that came from affective tests. For rating tests, initially the variance homogeneity should be assessed by dispersion graphs and Levene or Hartley tests. This procedure is demanding in order to guarantee the appropriateness of the application of mean differentiation tests: the means of samples ( $n \geq 3$ ) that present nonhomogeneous variances ( $P < 0.05$ ) should be compared with the Kruskal-Wallis multiple range test, and on the other hand, samples ( $n \geq 3$ ) that present homogeneous variances ( $P > 0.05$ ) by applying Levene or Hartley tests should be compared by Tukey, Duncan, Fisher LSD *posthoc* tests (Granato and others 2010b). Another issue that should be taken into



account is that homogeneous variances should also be assessed with the panelists' scores, which means that not only samples but also the variances of scores given by the panelists are important to render trustful results in sensory evaluation. For this purpose, 2-way ANOVA should be used to determine the overall significance for the main effects and interactions between test samples and assessors (Granato and others 2010c).

Farzanmehr and Abbasi (2009) investigated the influence of various ratios of prebiotics including inulin (IN), polydextrose (PD), and maltodextrin (MD) along with 0.04% (w/w) sucralose on physicochemical, mechanical, and sensory properties of low-sugar chocolate milk. Sensory attributes of chocolate milk including sweetness, firmness, melting rate, mouthcoating, color, and overall acceptability (sum of aforementioned 5 sensory attributes) were evaluated using a multiple difference test (4-point rating scale; 1 = undesirable, 2 = tolerable, 3 = good, 4 = desirable) based on a balanced incomplete block design by 7 trained panelists. In general, formulations with high ratios of PD and MD were moister and softer than the control. MD induced the least desirable sensory effects, whereas PD and IN pronouncedly improved the overall acceptability.

Kiliç and others (2008) used scorecards (cheese scorecards) to grade Turkish Beyaz probiotic cheese supplemented with *Lactobacillus fermentum* (AB5-18 and AK4-120) and *L. plantarum* (AB16-65 and AC18-82) toward the sensory quality of the product. Three batches of cheese were produced: the test probiotic culture mix (P), another with commercial starter culture mix including *Lactococcus lactis* ssp. *cremoris* and *L. lactis* ssp. *lactis* (C), and the third with equal parts of the commercial starter culture mix and test probiotic culture mix (CP). Sensory analysis was done by 16 panelists and cheese samples were graded on cheese scorecards according to the relevant Turkish National Standard. Panelists rated 35 points for flavor attributes, 35 points for body and texture, 20 points for appearance, and 10 points for odor. The sensory quality of P cheese was comparable to C cheese and it was found that the combination of the test probiotic culture and the commercial starter culture used had a positive effect on the sensory characteristics of Turkish Beyaz cheese.

Ayala-Hernandez and others (2009) carried out a study confirming the importance of the interaction between the exopolysaccharide (EPS) produced by *Lactococcus lactis* subsp. *cremoris* JFR1 and the proteins by the increase in viscosity of yogurts. By comparing the rheological properties of samples fermented by microorganisms that produced and did not produce EPS, the authors concluded that the interactions between EPS and the proteins were fundamental for structure formation, and could explain the mechanism of formation of the viscosity in fermented milk products. According to the authors, the production of highly viscous material could potentially be employed in the future as a new functional ingredient in dairy products. Thus, studies involving descriptive sensory profiles and consumer surveys should be applied to the products being compared, to obtain important information that can contribute to greater understanding of the group of results and their possible correlations.

Ong and Shah (2009) carried out studies to determine the descriptive sensory profile for probiotic Cheddar-type cheese. *Bifidobacterium longum* 1941, *B. animalis* ssp. *lactis* LAFTI R-B94, *Lactobacillus casei* 279, *L. casei* LAFTI L26, and *L. acidophilus* 4962 or *L. acidophilus* LAFTI L10 were used as adjuncts in the production of Cheddar cheeses, which were matured at 4 and 8 °C for 24 wk. The application of high maturation temperatures associated with the probiotic adjuncts was investigated with respect

to their effect on proteolysis and on the sensory analysis. High maturation temperatures increased the level of proteolysis in the cheeses. The proteolysis products and the organic acids liberated during maturation were reported as being important compounds in the formation of the typical Cheddar cheese flavor. Significant positive correlations between the levels of soluble nitrogen and of lactic, acetic, and butyric acids occurred during the maturation period. High scores for acid and vinegary flavors were obtained for cheeses with added *Bifidobacterium* spp. or *L. casei* 279 matured at 8 °C, and the scores were correlated in a positive or negative way with the levels of lactic and acetic acids and of free amino acids in the cheeses ( $P < 0.05$ ). These results showed the potential for using both 4 and 8 °C for the maturation of probiotic Cheddar cheese. Similarly, although a bitter taste is considered as a normal component of Cheddar cheese flavor, excessive bitterness can limit or even block acceptance of these products. With respect to the sensory attributes of cheddary, bitter, acid-sour, and vinegary in cheeses stored at 4 to 8 °C for 6, 12, and 24 wk, the scores for cheddary (characteristic flavor of Cheddar-type cheese) increased with storage time for all the cheeses. During the 1st stages of maturation, the cheddary flavor did not differ significantly ( $P > 0.05$ ) between the different batches, but after 24 wk of maturation, the scores for cheddary were greater in the cheeses matured at 8 °C than in those matured at 4 °C. This was probably due to the ripening process in which more peptides and free amino acids were freed into the cheese whey with time in the cheeses matured at 4 °C/8 °C. However, according to the authors, the probiotic treatment did not modify the scores for the attribute cheddary. Also, no significant correlation was observed between the levels of proteolysis and the scores for bitter taste in the cheeses. The scores for bitter flavor were also not significantly different between the cheeses with and without the probiotic culture at either temperature. This fact is particularly interesting as evidence that the scores for bitter flavor were reduced after 12 wk of maturation and increased again after 24 wk in the majority of the cheeses. Probably, the C-terminal residues 193 to 209 in the  $\beta$ -CN region and the C-terminal residue 1 to 9 in the 1-CN region could be associated with bitterness in cheeses (Lemieux and Simar 1992). The residues 193 to 209 of the  $\beta$ -CN are normally formed by the addition of chymosin. The addition of probiotic microorganisms to cheeses can significantly modify the scores for acid (which the authors listed as acid-sour) and vinegary tastes ( $P > 0.05$ ), sensory attributes that can also suffer important effects as a result of the maturation time, temperature, and interactions between probiotic microorganisms. The above-mentioned peptides are possibly broken during the 1st ripening stages, resulting in low scores for bitter taste after 12 wk of maturation. The acid-sour and vinegary attributes were positively correlated with the lactic and acetic acid contents.

Phang and Chan (2009) carried out a sensory profile using QDA in milk "kaya," a typically Malaysian food that is a type of emulsion made of coconut milk, supplemented with various concentrations (0, 10, 30, and 50% w/w) of inulin. Six descriptors were obtained by consensus among the taste panelists: brown color, sweetness, firmness, softness, adhesiveness, and spreadability. Differences in the means for the descriptors were observed, being related to variations in the concentration of inulin in the formulation. For the attribute of sweetness, it was possible to infer that the use of 30% w/w of inulin in the formulation did not alter the performance of the formulation in relation to the product with the addition of sucrose (0% w/w inulin). Also, the addition of the prebiotic showed a positive influence on product softness independent of

the concentration added, and no differences were observed with respect to spreadability. In general, it was noted that the only attributes receiving low scores from the trained panel due to the addition of inulin were firmness and adhesiveness.

Milesi and others (2009) used QDA in Cremoso cheese supplemented with nonstarter lactobacilli strains with probiotic potential, using a panel with previous experience of cheese sensory tests. Sensory profiles were very similar. The differences in the scores depended on the strain added. Control cheeses presented the highest score for creamy flavor, followed by cheeses with *L. casei* I90 and *L. plantarum* 91 and, finally, by cheeses with *L. rhamnosus* I73 and I77. The lowest scores for acid flavor were presented by cheeses with *L. plantarum* I91 and control cheeses, whereas the cheeses with *L. rhamnosus* I73 the highest. The addition of probiotic cultures maintained and/or even improved the sensory properties of the products.

Burns and others (2008) explored the potential of milk treated by high-pressure homogenization (HPH) on quality factors of Crescenze cheese fermented by *Streptococcus thermophilus* with/without probiotic lactobacilli, during 12 d of refrigerated storage. Twenty-five trained evaluators were asked to evaluate cheese color, flavor, firmness, appearance, acid, piquant, bitter, sweet, milky, salty, creamy, and overall impression attributing a score ranging from 0 (low or poor) to 10 (high or very excellent). No significant differences were found for the sensory descriptive salty and creamy among the HPH-treated and HPH-untreated (only pasteurized) samples as well as for acid, piquant, sweet, milky, salty, creamy, and overall acceptance among HPH-treated, HPH-treated plus probiotics, and HPH-untreated plus probiotics samples.

Messina and others (2008) reported use of the repertory grid method to evaluate European older people's perception toward conventional and functional (probiotic) yogurts. Fifty-six distinct verbalizations were noted, suggesting there are complex cognitive structures regarding these products. However, a predominance of some constructs as previous familiarity with the product, taste, natural product, and health benefits and nutritional content were noted. Overall, functional yogurts were clearly separated from conventional yogurts due to attributes like knowledge and familiarity with product/brand being represented by health benefit construct. The results indicate the importance of communicating in an easy way the benefits of functional products, in this case, probiotic ones, to the consumers, and emphasized by the food processors, without forgetting their sensory properties.

Consumers' food choice is a complex phenomenon affected by several factors: the 1st one is product-related (physical and chemical properties, sensory quality, and product packaging), the 2nd is consumer-related (age, gender, education, and physiological factors), and the 3rd and last one is the sum of environmental factors like economic, social, and cultural factors (Jaeger 2006). Recently, it has been reported that food choice is more completely understood according to the deductionist approach: it is highly dependent on situational factors, as the same person will appreciate the same food very differently in different situations. In this context, the consumer should not be seen like a unitary person, but as a variety of personalities which reacts in an unequal way according to the situation in which it is experienced; he/she will appreciate the same food very differently on different occasions (Koster 2009).

Frutos and others (2008) studied the modification in texture caused by the addition of artichoke fiber (0%, 3%, 6%, and 12% w/w) to bread formulations, substituting the wheat flour. Four

sensory attributes were evaluated (hardness, chewiness, cohesiveness, and elasticity) by 25 trained judges. The attributes of hardness, elasticity, and chewiness increased in intensity as the fiber concentration increased. Cohesiveness showed the opposite effect, decreasing with increase in fiber concentration. From the descriptive results obtained and the acceptance test, the authors concluded that the bread samples containing 3% and 6% w/w of artichoke fiber did not suffer great alterations as compared to the control (0% w/w artichoke fiber).

Ong and others (2006) showed that the addition of probiotic bacteria such as *Bifidobacterium* spp. and *Lactobacillus* spp. caused an increase in the acid concentration of cheeses, and for this reason the descriptor "vinegary" was added to the list of attributes, showing correlation between the concentration of acid obtained instrumentally and the sensory perception of a vinegary flavor in the cheeses. The attribute oak/nutshell, which corresponds to the flavor of premium quality Cheddar cheese (Partridge 2009) was changed to "cheddary" and defined as general Cheddar flavor (Hulin-Bertaud and others 2000).

Uysal-Pala and others (2006) evaluated the sensory characteristics of drinkable goat yogurts from different breeds and manufactured with normal and probiotic cultures. Eight descriptive terms were developed for the products, among them creamy, goaty, and astringent. Using probiotic cultures affected in a positive way the intensities of goaty, creamy, cooked, burnt, and astringent attributes, demonstrating their potential for improving the taste by decreasing the goaty flavor.

Güven and others (2005) used a trained panel composed of 5 members with previous experience in fermented products to evaluate the sensory attributes of color, appearance, texture, aroma, and overall impression of yogurts supplemented with 0%, 1%, 2%, and 3% inulin, with the objective of substituting the milk fat by the prebiotic. The sample without inulin showed the best performance for all the attributes, followed by the samples with increasing amounts of inulin.

Gallardo-Escamilla and others (2005) used Tragon's Method QDA (Stone and others 1974) to develop a sensory profile for milk whey fermented by lactic cultures traditionally used in the manufacture of cheese and yogurt and by probiotic cultures, using mass spectroscopy to determine the main compounds responsible for the flavor of these cultures. Eleven descriptors were raised, 5 for the attribute of aroma and 6 for the attribute of flavor. More than 50% of the sensory attributes were influenced by the lactic cultures, but only 3 were influenced by the medium used for fermentation. The media fermented by the probiotic cultures received high scores for the aroma of yogurt, aroma of fruit, and aroma of vinegar. Acetone, acetic acid, diacetyl, and acetaldehyde were the chemical compounds produced in greater concentrations in the media fermented by probiotic cultures.

Luckow and Delahunty (2004a) investigated functional juices (nondairy products) containing probiotics and prebiotics, commercially available in Europe. In the 1st stage, 10 judges were trained to determine the descriptive profile of 11 samples (7 were orange juices containing no functional element, and 4 were orange juices with an added probiotic, one being *Lactobacillus* GG, and/or prebiotic (fructooligosaccharides). In the 2nd stage, 100 consumers carried out an acceptance test. The functional orange juice samples presented a significantly different descriptive sensory profile from that of the conventional samples ( $P < 0.05$ ). The results of this study showed that, in general, consumers preferred the sensory characteristics of the conventional orange juice, when ingested with no additional information concerning the

product being tested. The sensory characteristics attributed to the functional orange juices included “lactic aroma, medicinal taste, artificial, and earthy.” Although these attributes were completely unacceptable to frequent consumers of conventional orange juice, they did not cause rejection by nonconsumers or infrequent consumers of the product in question. The authors stated that these results indicated the existence of a potential market for functional orange juice, since people who were nonconsumers of conventional orange juice preferred the attributes of the functional juices (11%) and another group of people (24%) liked the 2 types of juice equally. The authors concluded that the taste and aroma had a great impact on product acceptance, but that the acceptance could be modified if information about the health benefits of ingesting these products were provided to consumers.

Luckow and Delahunty (2004b) analyzed samples of conventional currant syrup and a sample with added *Lactobacillus plantarum*. A descriptive analysis revealed the presence of nontypical aromas and tastes in the syrup with added probiotic microorganisms, such as perfumed and lactic aroma and sour and salty tastes. In a study carried out with orange juice, the authors also found unusual aromas and flavors, such as lactic, medicinal, and salty taste, among others, reinforcing the fact that the addition of probiotic microorganisms alters the sensory profile of the final product.

La Torre and others (2003) developed a descriptive profile using QDA for probiotic and conventional yogurts fermented by the following strains: *L. acidophilus*, *B. longum*, *B. lactis*, and *B. infantis*. Eleven descriptors were elaborated after a discussion among the judges. Differences were observed for all these descriptors and were related to differences in the metabolism between the probiotic cultures and the starters, and also between the probiotic cultures themselves. The application of the chemometric tool, principal components analysis, allowed for 2 groups of product to be distinguished using the descriptor vinegary taste as the reference, once this is related to the metabolism of the Bifidobacteria, resulting in the production of a greater amount of acetic acid during storage of the product.

Allied to the alterations caused by the addition of functional ingredients to foods, studies are being carried out with a view to developing techniques to mask these undesirable flavors. The use of tropical fruits has had success in masking medicinal flavor and improving the sensory quality and acceptance of probiotic juices. Also, microencapsulation may be an interesting alternative to reduce the negative attributes that the probiotic cultures may cause in foods (Luckow and others 2006).

Delahunty and Murray (1997) and Murray and Delahunty (2000) defined a large number of descriptive terms to describe the sensory properties of Cheddar cheese. Drake and others (1996) selected specific attributes such as acid, oak-nutty, firmness, and crushed mint to define the sensory profile of Cheddar cheese made with the addition of *Lactobacillus* bacteria. Ong and Shah (2009) found similar terms with some modifications.

### Consumer attitude toward probiotic and prebiotic food products

Interest in the development of functional foods is increasing, noticeably directed to the market potential for foods and beverages that can benefit consumer health and well-being (Hillman 2000), although a consensus exists that consumers have little knowledge about these foods and what they signify or of the benefits of ingesting them. In general, this was not related to gender, age,

and educational or economic levels of the consumers (Vianna and others 2008).

The perceived healthfulness of a functional food might depend on the characteristics of the consumers and the type of carrier and enrichment considered; recent research reports that yogurt is perceived as a “healthy product,” due to a previous positive image to the consumers, and its enrichment with calcium and fiber the most preferred (Ares and Gámbaro 2007). Ingredients known as vitamins and mineral salts applied in the fortification of functional foods are widely recognized and accepted by consumers as important elements for a healthy organism, but new functional ingredients such as probiotics and prebiotics are less familiar to them. As a result, there is little knowledge concerning consumer acceptance with respect to these new special ingredients (Luckow and Delahunty 2004a).

The sensory impact that prebiotic or probiotic cultures can cause in foods or beverages to which they are added has been little studied, although it is understood that products to which these functional ingredients have been added can create different flavor profiles when compared to the conventional products (Matilla-Sandholm and others 1999). Roberfroid (2000) reported that oligofructose provides some suitable sensory properties to the products in which it is added, such as rounder mouthfeel, sustained of flavor with reduced aftertaste, and slight sweetness. These properties have been shown to be partly responsible for high score values for taste, creaminess, and acceptability of different food products.

Some studies (Tepper and Trail 1998; Tuorila and Cardello 2002) have shown that flavor is the 1st indicator with respect to the choice of a food, followed by considerations regarding health. These studies also indicated that consumers are not interested in consuming a functional food if the ingredients added contribute disagreeable flavors to the product, even if this results in advantages with respect to their health.

Tuorila and others (1994) showed that consumers who purchase foods motivated by a beneficial “healthy” effect may not consume the required amount to reach the necessary level to obtain the desired physiological effect, if they do not encounter the expected flavor. This means that flavor is not only correlated to intrinsic sensory properties of the product such as overall acceptability, but also with purchase intent.

It is extremely important to emphasize that despite the fact that the studies on this theme are contradictory, the same situation exists for other types of conventional products, such as milk, for example, where studies carried out by Vickers and others (1999) gave conflicting results with respect to acceptance of the oxidized flavor in milk, which was well accepted by one part of the population as a function of the demographic region in which they lived, since they received the milk a long time after its production and were therefore used to the oxidized flavor and even preferred this characteristic. Thus, consumption frequency and habit can drastically influence acceptance, demonstrating that with an increase in the consumption frequency of functional products, the acceptance of such products may increase, even if the sensory profiles are different from those of the conventional products.

When functional ingredients are added to foods, consumers must be aware of the health benefits of these ingredients in order to perceive the functional foods as being more beneficial than the conventional ones. How to communicate the beneficial effects on health in a way understandable to consumers is one of the most important aspects faced by the functional food industry (Oude Ophuis and Van Trijp 1995; Nicolay 2003; Vieira 2003).

Bruhn and others (2002) investigated the interest of consumers in probiotic products with respect to improvements in their health conditions and reported that consumer attitudes with respect to probiotic cultures were positive. However, according to the same authors, the consuming public would like to see the recommended amount for consumption and frequency to be included on the label.

Baixauli and others (2008) studied the influence of information on the fiber content of traditional, whole, and fiber-enriched muffins in an analysis with 102 consumers. The study was divided into 2 stages. In the 1st stage the sensory analysis was carried out without the consumers receiving any information concerning the samples, and in the 2nd stage, applied 1 wk later, the consumers received a pamphlet with information concerning the fiber content, and were asked to read it before starting the sensory test. The results showed that prior knowledge concerning certain nutritional information affected the way in which the consumer evaluated a designated product. The whole muffins received a lower score for acceptance when the evaluation was carried out with no information than when the consumers knew they had higher fiber contents than the traditional samples. The fiber-enriched muffins were enriched with resistant starch and their color was similar to that of the traditional muffins. Thus, the consumers did not believe that their fiber content was similar to that of the whole samples, which showed a color typical of whole products, and therefore the acceptance scores for the fiber-enriched samples continued to be low even after the consumers received the information about the fiber contents.

The Focus Group method, which studies the behavior of a consumer faced with a certain product (Stone and Sidel 2004) was applied to evaluate the attitudes of consumers with respect to the nutritional information on the label, identification concerning the presence of *Lactobacillus* or *Bifidobacterium*, also present on the label, and interest concerning potential benefits that the food containing these microorganisms might provide credibility of the product and an appropriate price for the probiotic products. Verbalizations were created that covered subjects such as a decrease in blood cholesterol levels, protection against heart disease, decrease in the risk of certain types of cancer, increase in the immune response, increase in resistance to the irritable bowel colon syndrome, and reduction in lactose intolerance (Ares and others 2008b). Another focus group study reported a limited knowledge about functional foods, emphasizing the sensory quality of these products must be attractive, as similar as possible to the traditional foods with respect to texture and flavor (Barrios and others 2008).

Another methodology, known as the Conjoint Analysis, was used to elucidate the attributes with greater significance in probiotic foods, in the perception of Italian consumers. The certification of the product by governmental authorities, the production mode, and the health claim obtained the greatest degree of importance, with 44%, 29%, and 26%, respectively (Saba and Rosati 2002). In another study carried out recently in Canada, the attributes most valued by the consumers, with means of importance of 40% and 25%, respectively, were the probiotic microorganism carrier food—yogurt—and the health claim provided by ingestion of the food—“contribution to the reduction of colon cancer” (Hailu and others 2009). The conjoint analysis is a technique that can be used in consumer studies to identify the attributes/levels that most influence choice, buying, and acceptance of the product. Different versions of the product are presented as from the combination of previously known factors/levels, thus determining the contribution of the levels of each of these factors—the part-worth of each

level/factor present in the study (Carneiro and others 2003). In probiotic and prebiotic foods, the use of CA can be useful for a better understanding of the knowledge of the consumer concerning the intrinsic attributes, which can lead to applying specific marketing strategies, guaranteeing the success of the probiotic food on the market.

There are basically 2 types of health claim used on package labels: “reinforces functions of the organism” and “decreases the risk of diseases” (Diplock and others 1999). Health claims of the type “reinforces functions of the organism” relate to consumption of the food or food component to health benefits of the individual, and “decreases the risk of diseases” relate to consumption of the food or food component to aiding in reducing the risk of a specific disease or of an undesirable state of health. The use of one of these claims depends on which will have the greater impact (Van Kleef and others 2005). Since consumers react better to positive attributes than to negative ones (Krishnamurthy and others 2001), claims concerning “reinforces functions of the organism” can be more attractive to the consumer than claims concerning “decreases the risk of diseases,” since the former evoke positive associations in the memory (Van Kleef and others 2005). Nevertheless, according to Ares and others (2009), the consumer reacts positively to both types of health claim.

Another determinant factor is the term chosen to demonstrate that the product is functional. In dairy desserts, the wholesomeness and the desire to experiment increase when the terms “fibers” and “antioxidants” appear on the labels when compared to conventional labels without such claims, indicating a positive attitude in relation to these functional ingredients (Ares and others 2009). If a functional food industry wishes to emphasize the use of a new ingredient, this should be declared on the label by stating its scientific name and health claim, so as to create an association in the consumer’s mind between the ingredient and its effect.

The factor of gender can also influence which is the best strategy for the concept on the label. In a study involving 150 persons in Uruguay, Ares and others (2008a) showed that women gave more importance than men to the nomenclature used to declare the addition of functional ingredients. This probably occurred due to the fact that women are more familiar than men with the effects on health caused by the use of fibers and antioxidants. In addition, older consumers were more interested in products that claimed short-term health benefits. Jezewska-Zychowicz (2009) reported that young Polish consumers are quite familiar with functional foods, although they are not consumed very frequently, with probiotic yogurts the most widely consumed product for the greatest group of students. Also, the need for functional food positively affected the willingness to use these products.

The Focus Group method is not a quantitative test, but it provides important information about the behavior of people in real situations, such as those encountered in supermarkets, especially concerning the knowledge people have about food products (Krueger 1994). It encourages communication and provides insights into how others think and talk, an important tool for detecting people’s needs that are poorly understood, because discussion among people provides a variety of useful data (McDonagh-Philp and Bruseberg 2000). Its main advantage is to allow much more freedom of expression by the participants than other forms of inquiries. In this method, the participants choose the way in which they will answer, allowing interaction, debate, and change of opinion during the discussion with the other participants, adding complexity to the qualitative information (Dransfield and others 2004). As it is exploratory research, a simple descriptive narrative is



appropriate for the analysis of the results (Stewart and Shandasani 1990).

The Focus Group technique can be used to evaluate the previous concept toward probiotic, prebiotic, and synbiotic foods, as well as the most preferred food carrier. It should help to build educational and clear messages about the advantages of these products aimed to facilitate the interaction between consumer and food product.

Ares and others (2008a) carried out a study to determine how much prior knowledge of nutrition influenced the consumer in recognizing benefits and the desire to experiment with a functional food. From these results, it was observed that consumers with high and medium knowledge about nutrition recognized that products with added fibers and antioxidants were more beneficial to health as compared to conventional formulations, whereas the opinion of consumers with less knowledge about nutrition was not altered by the addition of these ingredients to the products. Nevertheless, with respect to the reduction of lipids, independent of the degree of knowledge about nutrition, all the groups identified these foods as beneficial to the health, which could be associated with the fact that information about the health benefits related to a reduction in fat have been better communicated to the public than information about the benefits of the use of fibers and antioxidants in foods.

The results of these studies indicated the need for easily understood educational programs, using simple and clean language for the formation and fixation of the concepts related to these products, such that consumers show more interest in buying and experimenting with functional foods.

Bower and others (2003) reinforced this hypothesis by showing that consumers were willing to pay more and showed improved acceptance when informed about the health benefits probiotic products could provide, as opposed to other tests applied without this information. Nevertheless, the authors concluded that more studies are required to obtain a more consistent response.

## Perspectives

The importance of consuming prebiotic, probiotic, and synbiotic foods for improvement of the quality of life is clearly described in the scientific literature, and the number of foods to which they can be applied is increasing, as is the diversification of the agents that provide these characteristics in the products. Thus, knowledge of the descriptive sensory profile of the products, and also acceptance by consumers or potential consumers is fundamental to selling foods that can be consumed and appreciated.

In addition, the frequent showcasing of such foods and their gradual, but constant, introduction into catering should be considered, since this is an important way of familiarizing the populations with such foods, thus forming a marketing history making the consumption of these foods become a frequent and beneficial habit. It is also important to emphasize the need to divulge the properties of prebiotic, probiotic, and synbiotic foods, in order to make the populations of all educational levels aware of these foods, making it possible to build new important concepts such that these products, associated with existing products, could amplify their knowledge about foods with sensory and especially nutritional quality.

Another issue that should be emphasized here is the need of a professional with experience in a sensory testing department of a company in the academy fields to perform the most suitable tests, analyze the data with right statistical techniques, and present the results in a comprehensive and clear way to the consumers/researchers/plant managers. In this regard, more attention on sensory analysis in the field of prebiotic, probiotic, and synbiotic

food products will be paid and more consensual and trustworthy data will be available for general use.

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