Probiotics in Bread and Baked Products: A New Product Category

J. Côté¹
Lallemand Bio-Ingredients
Montreal, QC, Canada

J. Dion
L.V. Lomas Limited
Montreal, QC, Canada

P. Burguière
Lallemand Health Solutions
Montreal, QC, Canada

L. Casavant and J. Van Eijk
Lallemand Baking Solutions
Montreal, QC, Canada

The fastest growing market for probiotics is the food industry. Depending on the product and geographic region, sales of foods containing probiotic bacteria have increased from 7 to 32% each year (11,16). In fact, many consumers indicate they prefer probiotic-enriched foods to probiotic pills and supplements (2).

The origin of consumption of probiotic foods for their potential health benefits dates back to the beginning of the 20th century. In 1908 Elie Metchnikoff, who received a Nobel prize at the turn of the 20th century for his work on immunology, advocated eating fermented milk products to prolong life (13). Since then, probiotics have been the subject of thousands of scientific publications. Probiotics are defined by FAO/WHO (9) as live microorganisms that, when ingested in adequate amounts, confer a health benefit to the host.

Role of Gut Microbiota

The gut microbiota have evolved in step with human physiology, and this symbiotic process has left the modern human gut teeming with bacterial cells, mostly located in the colon: about 100 trillion cells in total, representing more than 1,000 species of bacteria (8,23). This intestinal microbiological activity, often referred to as the intestinal flora, plays an important role in maintaining health. By shaping and maintaining normal mucosal immunity, the intestinal flora forms a “barrier effect.” The presence of these beneficial bacteria in the intestinal tract helps prevent colonization of the intestine by pathogens and thereby helps the body defend against infections (Fig. 1).

The microbiota in the colon are also involved in completion of the digestive process through fermentation of substances such as dietary fiber, oligosaccharides, fructose, and lactose that are not digested in the stomach or small intestine. Carbohydrate fermentation produces short-chain fatty acids, especially butyrate, which is the primary energy source for the cells lining the colon. When butyrate levels are reduced or absent, inflammation characteristic of ulcerative colitis can result. Finally, gut microbiota have also been shown to assist with amino acid and vitamin K synthesis and with metabolism of bile acids, other sterols, and xenobiotics (1,17).

The intestinal flora is in a constant state of flux, and the delicate balance between microbes can be disturbed by diet, alcohol, contaminated foods, antibiotics, stress, and aging, as well as by digestive disorders and diseases (5). Altered composition of the microbiota (dysbiosis), e.g., an increase in pathogenic bacteria or decrease in beneficial bacteria, may decrease the barrier effect and contribute to the appearance of various digestive ailments, including bloating, intestinal upset, constipation, dyspepsia, allergies, etc. This, in turn, may lead to the development of more serious conditions such as ulcerative colitis, Crohn’s disease, irritable bowel syndrome, obesity, type 1 and type 2 diabetes, and celiac disease (10,14).

The probiotic concentration in foods is expressed in colony forming units (cfu) per gram of serving, which is an indication of the number of live microorganisms present. To date, there is no recognized colony forming unit level of probiotic bacteria in foods that would guarantee biological activity (18). However, on average, levels required to achieve beneficial effects from foods containing probiotics are commonly reported to be >100 million (10⁹) viable cells/day (3,6,7).

Addition of Probiotics to Bread and Baked Products

A wide variety of probiotic strains are now being added to an array of foods. Probiotics are most often found in dairy products, but they are increasingly being incorporated into other food products as well (e.g., juice, granola bars, chocolate, cereal, etc.). The majority of probiotic microorganisms are lactic acid-producing bacteria, which are usually part of a healthy intestinal flora. Lactobacillus and Bifidobacterium strains are most commonly added to foods and supplements (20). Enterococcus spp., Bacillus spp., Escherichia coli, and Saccharomyces boulardii (nonpathogenic yeast) are more commonly sold as supplements but can also be added to foods (20).

The viability of probiotics in foods depends on various conditions encountered during processing and storage. The loss of probiotics during thermal processing depends on the ability of a strain to withstand heat (4,12). Most probiotic bacteria are sensitive to heat, so their survival during thermal processing is a major obstacle. The heat involved in baking can result in significant losses in viability dur-

¹ Corresponding author. Lallemand Bio-Ingredients, 1620 Prefontaine, Montreal, QC H1W 2N8, Canada; E-mail: jcote@lallemand.com

http://dx.doi.org/10.1094/CFW-58-6-0293
©2013 AACC International, Inc.
ing the manufacture and storage of breads and baked goods.

*B. subtilis* is a spore-forming bacteria that has the capacity to sporulate when exposed to harsh environmental conditions (15). This property confers a major advantage when *B. subtilis* is used as a probiotic in food manufacturing processes that use high temperatures, such as baking. When in its sporulated form, *B. subtilis* can survive heat shock, low pH conditions, high compression, high acidity, high water activity, and high sugar content (21). Thus, it can be incorporated at any step in bread and baked good production processes.

The probiotic *B. subtilis* R0179 has been used for more than 15 years to support gut health. This strain remains stable under industrial production processes such as baking, freezing, and extrusion and, as a result, is an excellent candidate for incorporation as a probiotic in a variety of food products.

The stability of *B. subtilis* R0179 under the conditions encountered in bread and baked good production processes was investigated. The probiotic was added to the dough with the other ingredients, and the concentration of probiotic after baking was analyzed throughout the shelf life of the bread (21 days). To guarantee probiotic concentrations of $10^8$–$10^9$ cfu at the end of its shelf life, the bread was inoculated with levels averaging $10^{10}$ cfu/50 g serving. The results shown in Figure 2 indicate that the concentration of *B. subtilis* R0179 was maintained well above $10^8$ cfu/serving during the 21 day shelf life of the bread. The stability of this probiotic in cookies baked for 6 min at 500°F and stored at room temperature for 12 months was also investigated. The concentration of *B. subtilis* R0179 remained higher than $10^9$ cfu/serving during the entire 12 month shelf life of the cookies (Fig. 3).

The addition of other well-known probiotic strains, such as *L. rhamnosus*, to bread and baked products was also investigated. The use of this strain in food is of great interest because it is well known to consumers due to effective marketing strategies utilized by dairy companies. Because *L. rhamnosus* R0011 is not heat-stable, it was applied to baked bread using a novel spray-on technology. When sprayed over bread after baking, *L. rhamnosus* showed good stability throughout the shelf life of the bread (21 days) at room temperature. The probiotic concentration remained higher than $10^9$ cfu/50 g serving of bread during the shelf life of the product (Fig. 4).

**U.S. Regulations and Claims for Probiotics in Breads and Baked Products**

In the United States, *B. subtilis* and *L. rhamnosus* both have been granted GRAS (Generally Recognized As Safe) status and are eligible for label claims. However, the FDA has not approved any health claims for probiotics. In addition, nutrient content claims cannot be made, because a daily value has not been established (19).
The most common claims seen in the marketing of probiotics are structure/function claims.

Structure/function claims describe the role of a nutrient or dietary ingredient that affects normal structure or function in humans. In addition, they may characterize the means by which a nutrient or dietary ingredient acts to maintain structure or function, or they may describe a feeling of general well-being purported to be associated with consumption of a nutrient or dietary ingredient (22).

Examples of structure/function claims currently used with products containing probiotics include claims that the probiotic strengthens the body’s defenses, cares for the digestive system, enhances “joie de vivre,” helps naturally regulate the digestive tract, and/or helps regulate the digestive system by helping to reduce long intestinal transit times (19). The addition of probiotics such as *B. subtilis* and *L. rhamnosus* to breads and baked goods, thus, can be promoted on the packaging label using these types of structure/function claims.

Summary
There is a growing market for foods that contain probiotic bacteria, and a wide variety of probiotic strains are now being added to an array of food products. The heat-stable probiotic strain *B. subtilis* R0179 was successfully added to bread and cookie formulations. When sprayed on baked bread, the heat-sensitive probiotic strain *L. rhamnosus* R0011 also showed good stability over a shelf life of 21 days. In the United States, breads and baked products containing probiotics can be marketed using structure/function claims.

Fig. 4. Stability of probiotic *Lactobacillus rhamnosus* R0011 sprayed over bread during a shelf life of 21 days.

References
9. FAO/WHO. Health and nutritional prop-
Jacinthe Côté is the scientific advisor for Lallemand Bio-Ingredients. She is a registered dietitian and holds an M.S. degree in food science from McGill University and a Ph.D. degree in biology from Université du Québec à Montréal. She is the author of a weekly nutrition column published in La Presse (a daily newspaper published in Canada) and of a book on obesity. For many years she provided technical support for different food manufacturers.

Joanie Dion is a technical sales representative for L.V. Lomas Limited. She holds a B.S. degree in microbiology from the University of Sherbrooke. She formerly worked for Lallemand Bio-Ingredients, providing technical support and promoting the use of probiotics in food applications in general and in baked goods in particular.

Pierre Burguière is the manager of the preclinical program on probiotics for Lallemand Health Solutions. He is responsible for probiotic characterization, host–bacteria interaction studies to determine their mechanisms of action, as well as development and validation of analytical methods. He is a microbiologist and holds a Ph.D. degree from Université Denis Diderot-Paris 7, where he studied *Bacillus subtilis* sulfur metabolism and its regulation at the Institut Pasteur. He worked for many years for Danone in analytical microbiology and molecular biology and then in research on probiotic health benefits.

Luc Casavant is the manager of the R&D and application laboratory for Lallemand Baking Solutions. He holds a B.S. degree in biochemistry and M.S. degree in chemistry from Université du Québec à Montréal. He worked for more than 15 years as a baker and production manager for Gadoua and Robin Hood bakeries. Luc is an AACCI member and can be reached at lcasavant@lallemand.com.

Jan van Eijk is the research director for Lallemand Baking Solutions and holds an M.S. degree in biochemistry, microbiology and food science from the Agricultural University of Wageningen and a Ph.D. degree in biochemistry from the State University of Utrecht. He has 30 years of experience in the baking industry and manages a team involved in the development of enzyme-based dough conditioners for the U.S. market. Jan is an AACCI member and can be reached at jvaneijk@lallemand.com.