The Magic and Challenges of Sprouted Grains

J. Pagand,[1,2] P. Heirbaut,[1] A. Pierre,[1] and B. Pareyt[1]

ABSTRACT

Grains, seeds, and pulses are important sources of energy in the human diet. In response to consumer demands for healthy, natural, and naturally processed foods, interest in sprouted grains has increased over the last decade, as demonstrated by the increasing number of sprouted grain products being launched every year. In this article, we discuss some of the reasons for the growing consumer interest in sprouted grains and how food manufacturers can take advantage of the "healthy halo" that surrounds these grains. Although there are regulatory challenges in communicating the nutritional and health benefits associated with sprouted grains to consumers, there are other qualities that differentiate sprouted from nonsprouted grains that can be used to promote the consumption of sprouted grains, most notably their unique flavor profiles.

Cereals, pseudocereals, and pulses are important components of most diets, providing good sources of energy, as well as macro- and micronutrients. Their consumption as whole grains is promoted based on their nutrient content and the health benefits they offer. In addition, a global consumer study conducted by Puratos in 2015 (Taste Tomorrow, [www.tastetomorrow.com/research]) shows that consumers are demanding health-promoting foods and ingredients that come directly from the earth or have been processed using natural methods. Sprouted grains fit perfectly with this consumer quest for health-promoting products. Sprouting is a natural process that occurs when a grain transforms into a plant and has been used since ancient times to enhance the nutritional value of grains. The process is somewhat similar to malting, which is used extensively in the brewing and distilling industries. However, malted grains are produced using additional processing steps (e.g., removal of the rootlet and culm and roasting), and their applications, flavors, and functionality (e.g., the enzymes remain active) differentiate malted from sprouted grains (23). This article will focus on sprouted grains.

According to legend, more than 5,000 years ago Chinese physicians prescribed consumption of sprouted grains to treat several disorders. In the 1700s, sailors consumed sprouts during long voyages to prevent scurvy, a disease caused by a lack of vitamin C in the diet. Shurtleff and Aoyagi (33) report that in the early 1940s Dr. Clive McKay, professor of nutrition at Cornell University, and his team began studying the properties of sprouted soybeans. They found that sprouted soybeans contained high levels of both vitamins A and C and also retained levels of B vitamins similar to those present in the original (nonsprouted) seed (33). In spite of these benefits, until recently harvested sprouted grains were typically considered to be defective, as indicated in European Regulation (EU) No. 1272/2009 (10). Since 2000, however, consumers have become increasingly interested in the potential nutritional properties of sprouted grains, and in response, food manufacturers have launched a number of products containing sprouted grains.

Today, grain sprouting is no longer an uncontrolled process. The process is well controlled with the goal of developing safe and healthy sprouted grains, seeds, and pulses with an optimal, enriched nutrient content. There are three primary phases in the controlled sprouting process. In the first phase, the grains are soaked to reach a moisture content around 45%. In the second phase, the endogenous grain metabolism that is necessary to mobilize storage materials (i.e., starch and protein) is activated. At the end of the second phase the radicle emerges and becomes visible. During the third phase, the seedling begins to grow, and the seed takes up more water. Different constituents are transformed by active enzymes during sprouting, and vitamins and minerals are made available for the embryo (N. De Brier, E. Lemmens, A. Moroni, P. Hierbaut, and J. Pagand, unpublished review on sprouted grains; 29).

Sprouted Grains Are Gaining Traction

Between 2006 and 2016 interest in products containing sprouted grains increased worldwide. Between 2006 and 2011, there was an average increase of 14% per year in the number of products launches containing sprouted grains. Between 2012 and 2016, the average yearly increase in product launches was 26% (Fig. 1). Based on a search of Mintel market data (www.mintel.com) using the terms "sprouted," "sprout," "germinated," and "freshly sprouted," including all categories, countries, positionings, flavors, and ingredients; excluding brussels sprout powder, brussels sprout juice, and brussels sprouts; and limited to products launched within the 2006–2016 timeframe, this trend in product launches was observed mainly in North America, followed by Europe and Australasia.

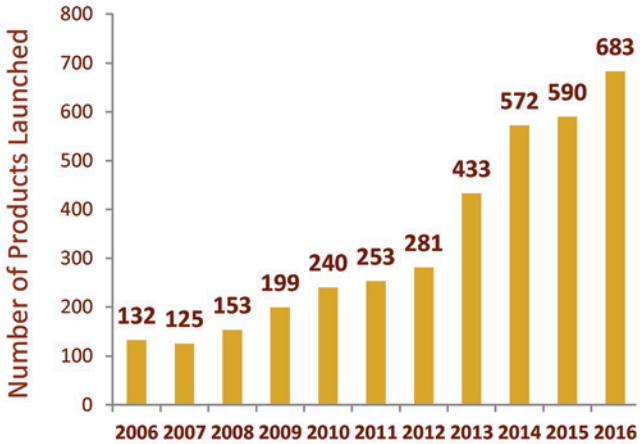

Fig. 1. Number of new product launches (2006–2016) containing sprouted grains based on a search of Mintel market data (www.mintel.com) using the terms "sprouted," "sprout," "germinated," and "freshly sprouted," including all food categories, countries, positionings, flavors, and ingredients and excluding brussels sprout powder, brussels sprout juice, and brussels sprouts.

[1] Puratos NV, Industrialaan 25, B-1702 Groot-Bijgaarden, Belgium.

[2] Corresponding author. E-mail: JPagand@puratos.com

http://dx.doi.org/10.1094/CFW-62-5-0221

Sprouted grains are gaining market share in a number of product categories. Mintel market data (www.mintel.com) was searched for new product launches containing sprouts globally per category using the terms "sprouted," "sprout," "germinated," and "freshly sprouted," including all categories, countries, positionings, flavors, and ingredients and excluding brussels sprout powder, brussels sprout juice, and brussels sprouts. From January 2015 to April 2017, the market category with the most product launches was snacks (22% of all products launched) followed by meals (19%) and bakery products (15%) (Fig. 2). The number of bakery products launched per bakery subcategory over the same period is summarized in Figure 3. Mintel market data (www.mintel.com) was searched using the same terms and timeframe. Bread and bread products topped the list of bakery subcategories, with 84 products launched. This suggests that bread products are good matrices for including sprouted grains and for advertising their inclusion.

The Reasons for the "Healthy Halo" Surrounding Sprouted Grains

Sprouted grains are very much in line with what today's consumers are looking for, i.e., ingredients that are perceived as natural, nutritious, and healthy. This positive perception was demonstrated in a large-scale consumer study ($N > 24{,}500$) conducted by Canadean (now GlobalData), which asked consumers, "Do you think the following ingredients will have a positive or negative impact on your health?" More than two-thirds (70%) of the participants responded that sprouted grains have a positive impact on health, while only 4% responded that they have adverse effects; 18% of the responses were neutral, and 8% of participants indicated they were not familiar with sprouted grains (6).

The "healthy halo" that surrounds sprouted grains is a result of the many reports in the media attributing specific nutritional properties to sprouted grains and of the positive images associated with the concept of a grain giving life to a new plant. However, it is important to understand whether these reports are based on credible information. In the following section we discuss some of the perceived benefits of sprouted grains and attempt to highlight the truths and myths surrounding them.

Sprouted Grains as Whole Grains

Sprouted grains are considered whole grains. AACC International (1) approved the following statement in 2008:

> Malted or sprouted grains containing all of the original bran, germ, and endosperm shall be considered whole grains as long as sprout growth does not exceed kernel length and nutrient values have not diminished. These grains should be labeled as malted or sprouted whole grain.

A second statement issued by the European Union on sprouted grains is related to fiber. According to EU Regulation (EC) No. 1924/2006 (11) it is possible to claim that sprouted grains are a "source of fibers" or are "rich in fibers" depending on their fiber content.

Nutrient Content of Sprouted Grains

It is generally believed that sprouted grains contain higher levels of vitamins and minerals than nonsprouted grains. However, when looking at the existing scientific evidence, the results are mixed (28), and the published studies are difficult to compare because the types and varieties of grains, soaking conditions (water quality), germination conditions (duration and temperature), and measurement methods differ from one study to another. Several studies (8,9,13,14,17,19–22,27,31,36–39) reported an increase in the levels of some vitamins and minerals with sprouting, while other studies reported no impact or even reduced levels of some vitamins and minerals (2,8,9,17,19,30,31,35). A summary of the results observed for two vitamins, B_9 and E, across various studies is provided in Table I. Results have been recalculated based on dry matter content and compared with the reference intakes (RI) described in European Regulation (EU) No. 1169/2011 (12) to determine whether nutritional claims can be made. The results indicate that the addition of sprouted grains and pulses to a formulation has the potential to result in a final product with higher values for some vitamins

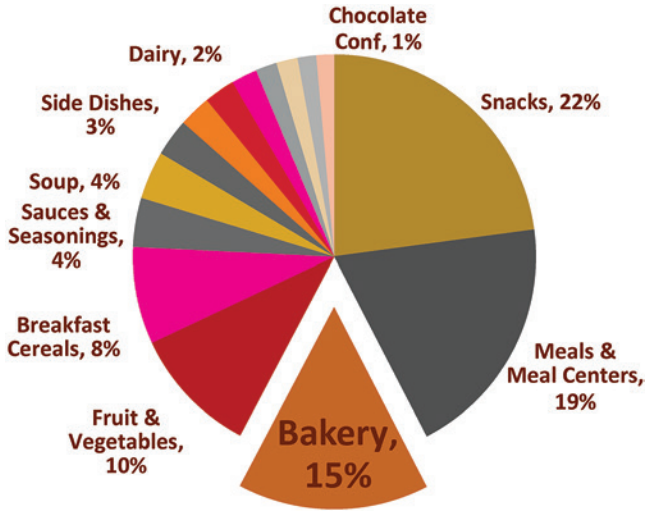

Fig. 2. Percentage of new product launches containing sprouts globally per category (January 2015 to April 2017) based on a search of Mintel market data (www.mintel.com) using the terms "sprouted," "sprout," "germinated," and "freshly sprouted," including all food categories, countries, positionings, flavors, and ingredients and excluding brussels sprout powder, brussels sprout juice, and brussels sprouts.

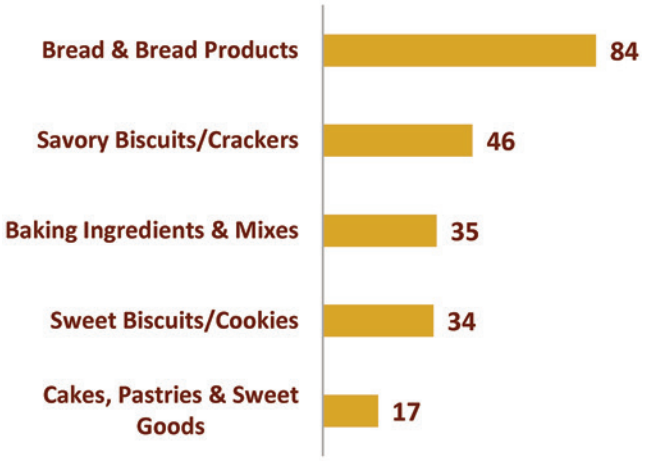

Fig. 3. Number of new product launches containing sprouts per bakery subcategory (January 2015 to April 2017) based on a search of Mintel market data (www.mintel.com) using the terms "sprouted," "sprout," "germinated," and "freshly sprouted," including all food categories, countries, positionings, flavors, and ingredients and excluding brussels sprout powder, brussels sprout juice, and brussels sprouts.

and minerals. However, this depends on the type of grain and the sprouting process used and does not apply for all vitamins and minerals. Making claims such as "increased in [vitamin/mineral]," thus, remains possible but challenging and depends on the grain and the conditions used to sprout the grain. It also is important to remember that sprouted grains only represent part of the manufactured product (e.g., 15% of the wheat flour mass in bread), which makes use of the above claims even more challenging. Finally, if it is difficult to make the claim "increased in [vitamins/minerals]," other nutritional claims, such as "source of [vitamins/minerals]" or "rich in [vitamins/minerals]," shouldn't be forgotten and may be a way to highlight a particular nutrient for which the requirements are easier to meet. For instance, a multigrain bread developed by Puratos that contains more than 10% sprouted grains (based on total dry ingredients) is allowed a "source of copper, zinc, magnesium and phosphorus" claim.

Bioavailability of Micronutrients in Sprouted Grains

Another property often mentioned is that micronutrients in sprouted grains are more bioavailable than in nonsprouted grains. Whole grains, seeds, and pulses contain significant amounts of phytates (25), which can form complexes with vitamins and minerals, making them unavailable for absorption by the body. Phytates show particularly strong affinities for minerals such as potassium, iron, magnesium, calcium, zinc, copper, and manganese (28). During sprouting, a portion of these naturally occurring complexes in grains, seeds, and pulses are degraded, which increases the bioavailability of the micronutrients. Degradation of phytates during sprouting/germination has been observed in many studies and in different grains, such as millet (17,26,27,34), sorghum (26,36), and rye and wheat (7,25). Germination time has been positively correlated with the extent of phytate degradation. A 20–30% reduction has been observed after 4 days of germination (2,3,5), but reductions as high as 80–85% can be reached after 10 days (4) (Fig. 4). Larsson et al. (24) found that the consumption of malted oat porridge, which contained 77% less phytate compared with its nonmalted counterpart, doubled the amount of zinc absorbed in healthy humans. In contrast, Tatala et al. (35) reported no significant effects of consumption of sprouted millet porridge on the iron status of Tanzanian children suffering from anemia compared with a similar group of children who received nonsprouted millet porridge. Existing data strongly suggest that the process of sprouting enhances the bioavailability of minerals due to degradation of phytate–mineral complexes by the action of phytase (4,5). However, more clinical trials are needed to confirm that this observation is directly linked to higher absorption of minerals in humans.

Digestibility of Sprouted Grains

Sprouted grains are also reportedly "easier to digest." According to *The American Heritage Stedman's Medical Dictionary* (2002 edition), digestion is

> The process by which food is converted into substances that can be absorbed and assimilated by the body, especially that accomplished in the alimentary canal by mechanical and enzymatic breakdown of foods into simpler chemical compounds.

Thus, it seems logical that foods in which the complex molecules have been entirely or partially broken down before being consumed would be easier to digest.

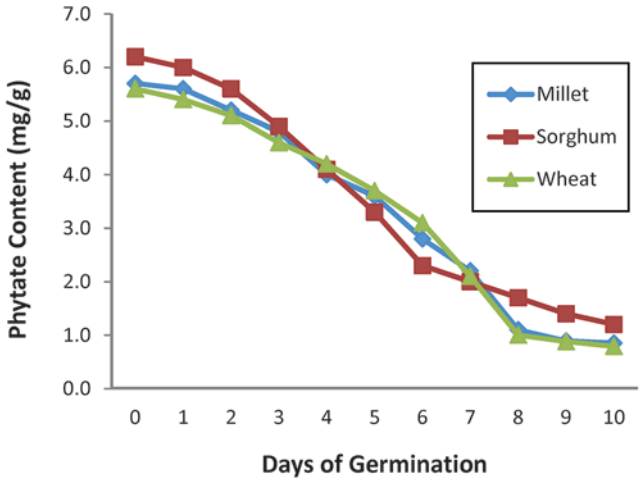

Fig. 4. Phytate content in three types of grains as a function of germination time. Based on data from Azeke et al. (4).

Table I. Comparison of vitamin B_9 (folate) and E contents in grains before and after sprouting across several studies of various cereals and pulses[a]

					Before Sprouting	After Sprouting	
	Grain	Variety or Latin Name	Study	Sprouting Duration	% of RI (per 100 g, dm)	% of RI (per 100 g, dm)	% Increase/Decrease (absolute value)
Vitamin B_9							
(RI = 0.2 mg)	Wheat	Tommi	Koehler et al. (22)	102 hr	29	100	245
	Wheat	Olivin	Hefni and Witthöft (14)	96 hr	10	67	565
	Rye	Not mentioned	Kariluoto et al. (20)	7 days	35	120	243
	Rye	Amilo	Katina et al. (21)	6 days	31	109	256
	Rye	Kaskellot	Hefni and Witthöft (14)	96 hr	18	71	306
Vitamin E							
(RI = 12 mg)	Wheat	Not mentioned	Yang et al. (39)	8 days	4	9	150
	Foxtail millet	*Seteria italica* (L.) Beauv. or *Panicum italicum* L.	Coulibaly and Chen (9)	1–8 days	1	3	75
	Soybean	Not mentioned	Chandrasiri et al. (8)	5 days	84	134	59
	Wheat	*Triticum aestivum* L.	Plaza et al. (31)	96 hr	3	2	–48
	Soybean	*Glycine max* (L.) Merr.	Plaza et al. (31)	96 hr	1	5	564

[a] RI: reference intake.

During germination, numerous enzymes are released, resulting in the degradation of complex molecules such as proteins and carbohydrates into smaller molecules (28). Degradation of protein results in an increase in peptides and/or free amino acids. Hung et al. (18) reported a 260% increase in free amino acid levels in wheat grains after 2 days of germination. Afify et al. (3) observed a much smaller increase (11%) in sorghum after 3 days of germination. During sprouting, starch stored in the endosperm is hydrolyzed by amylases, yielding oligosaccharides and small sugars (28). Jood and Kapoor (19) observed a 30% reduction of starch and 400% increase of sugars (2.9 mg to 11 g per 100 g of flour in millet) after 1 day of germination, whereas Hung et al. (18) found the starch level decreased by 1% after 12 hr of germination. Thus, the extent of degradation varies depending on the grain and germination process.

Even though there is strong evidence that sprouting can improve the nutritional profile of grains, claims related to the bioavailability of vitamins and minerals and ease of digestion of sprouted products have not been approved by either the European Commission or the United States. This limits the opportunities for food manufacturers to communicate directly with consumers about the nutritional benefits of products containing sprouted grains. Highlighting the use of sprouted grains in a product through the product name or in a front-of-pack claim, such as "made with sprouted grains" or "contains *X*% of sprouted grains," can help manufacturers take advantage of the "healthy halo" that surrounds sprouted grains.

Unique Flavor Profile of Sprouted Grains

The Puratos Taste Tomorrow study (www.tastetomorrow.com/research) revealed that consumers are attracted to food products and ingredients that are healthy, fresh, and tasty. Products made with sprouted grains appear to meet consumer demands for two of these qualities: taste and health benefits. As discussed in previous sections, sprouted grain products can be linked to nutritional and health benefits. However, other characteristics, such as flavor, could be highlighted to promote products containing sprouted grains.

One of the beneficial characteristics of sprouted grains is their flavor profile. Due to the activation of endogenous amylolytic enzymes, complex starch molecules are transformed into simple oligosaccharides and sugars. This transformation adds natural sweetness to products when sprouted grains are used, which could help manufacturers reduce levels of added sugar in products. Also, protein polymers are transformed into peptides and amino acids. During food processing, simple sugar molecules, free amino acids, and peptides can act as flavor precursors of odor-active compounds (16). More than 30 volatile compounds have been identified in thermally treated rye malt extracts, including pyrazines, pyrazoles, pyranones, pyridines, pyrimidines, furans, furanones, phenols, esters, aldehydes, ketones, and alcohols (15,32). This distinguishes sprouted grain products from their nonsprouted counterparts, suggesting that the unique flavor of sprouted grains can be a further benefit for promoting products containing sprouted grains.

Table II. Comparison of aromatic profiles of two multigrain breads (nonsprouted versus sprouted grains) using the free-profiling method[a]

Aroma	Nonsprouted Grain Bread	Sprouted Grain Bread
Fermented	Yeasty	Fruity
Vegetal	Herbal/hay[b]	Woody
Brown notes	Nutty	Malted
Mild		Honey[b]

[a] Data source: Puratos in-house expert panel study (an expert sensorial descriptive test); $N = 8$.
[b] Primary notes; all other aromas are secondary notes.

To test this theory, an in-house expert panel study was conducted by Puratos—an expert sensorial descriptive test of sprouted multigrain bread versus nonsprouted multigrain bread. The breads were presented to a panel of eight experts for individual profiling. The panelists were given a list of 17 aroma descriptors and asked to select the descriptors they could perceive in each bread. The final descriptors for each bread were the ones for which there was a consensus among the panelists: primary notes that were selected by at least six panelists; secondary notes that were selected by at least three panelists. The control bread (nonsprouted grains and pulses) was described as having a malted, yeasty, nutty aroma with herbal notes, whereas the bread made with sprouted grains and pulses was described as having naturally sweet, malted, fermented, fruity, and roasted notes (Table II). The hypothesis that the flavor of bread made with sprouted grains would be preferred over bread made without sprouted grains was tested in 2016 by Puratos using a consumer panel with 122 consumers who participated in a Sensobus (mobile sensory analysis lab) preference test of sprouted grain bread versus nonsprouted grain bread. The panelists received a 50% whole meal bread with 25% added grains that were either nonsprouted (control) or sprouted. The study found that 58% of respondents had a preference for one of the two breads, of which 75% preferred the sample prepared with sprouted grains.

Conclusions

Products made with sprouted grain are a growing segment in the food industry and trend projections suggest consumption will continue to increase. Still a niche market 15 years ago, products with sprouted grains are now represented in all categories, including snacks and bakery products. One reason for their increased use appears to be the consumer perception of sprouted grains as healthy, which is widely supported by messaging found across food blogs and health magazines. After reviewing the science behind sprouted grains, it appears that sprouted grains can offer superior nutrition compared with nonsprouted grains, depending on the specific grain and sprouting conditions. Currently European and American food manufacturers are not allowed to communicate some of the potential benefits of sprouted grains, such as bioavailability of micronutrients or digestibility. Sprouted grains do present other properties, however, that are as relevant to consumers as their nutritional benefits. By further processing sprouted grains, unique flavor profiles can be achieved. Selecting appropriate sprouted grains with desirable differentiated flavor profiles will provide food manufacturers with a message they can communicate to consumers while benefiting from the "healthy halo" that surrounds these grains.

Acknowledgments

We thank Julie M. Jones (professor emerita, St. Catherine University, St. Paul, MN, U.S.A.) for her valuable input.

References

1. AACC International. Whole grains. Published online at www.aaccnet.org/initiatives/definitions/Pages/WholeGrain.aspx. The Association, St. Paul, MN, 2008.

2. Afify, A. E.-M. M. R., El-Beltagi, H. S., El-Salam, S. M. A., and Omran, A. A. Bioavailability of iron, zinc, phytate and phytase activity during soaking and germination of white sorghum varieties. PLoS One. DOI: https://doi.org/10.1371/journal.pone.0025512. 2011.
3. Afify, A. E.-M. M. R., El-Beltagi, H. S., El-Salam, S. M. A., and Omran, A. A. Protein solubility, digestibility and fractionation after germination of sorghum varieties. PloS One. DOI: https://doi.org/10.1371/journal.pone.0031154. 2012.
4. Azeke, M. A., Egielewa, S. J., Eigbogbo, M. U., and Ihimire, I. G. Effect of germination on the phytase activity, phytate and total phosphorus contents of rice (*Oryza sativa*), maize (*Zea mays*), millet (*Panicum miliaceum*), sorghum (*Sorghum bicolor*) and wheat (*Triticum aestivum*). J. Food Sci. Technol. 48:724, 2011.
5. Bartnik, M., and Szafrańska, I. Changes in phytate content and phytase activity during the germination of some cereals. J. Cereal Sci. 5:23, 1987.
6. Canadean. Canadean Consumer's 2015 Q2 Global Survey: Canadean Consumer's Product Launch Analytics. GlobalData Plc., London, 2015.
7. Centeno, C., Viveros, A., Brenes, A., Canales, R., Lozano, A., and de la Cuadra, C. Effect of several germination conditions on total P, phytate P, phytase, and acid phosphatase activities and inositol phosphate esters in rye and barley. J. Agric. Food Chem. 49:3208, 2001.
8. Chandrasiri, V., Bau, H. M., Villaume, C., Giannangeli, F., and Méjean, L. Effect of germinated and heated soybean meals on plasma cholesterol and triglycerides in rats. Reprod. Nutr. Dev. 30:611, 1990.
9. Coulibaly, A., and Chen, J. Evolution of energetic compounds, antioxidant capacity, some vitamins and minerals, phytase and amylase activity during the germination of foxtail millet. Am. J. Food Technol. 6:40, 2011.
10. European Commission. Regulation (EU) No 1272/2009 of 11 December 2009 laying down common detailed rules for the implementation of Council Regulation (EC) No 1234/2007 as regards buying-in and selling of agricultural products under public intervention. Off. J. Eur. Union L349:1, 2009.
11. European Parliament, Council of the European Union. Corrigendum to Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. Off. J. Eur. Union L12:3, 2007.
12. European Parliament, Council of the European Union. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. Off. J. Eur. Union L304:18, 2011.
13. Fernandez, M. L., and Berry, J. W. Nutritional evaluation of chickpea and germinated chickpea flours. Plant Foods Hum. Nutr. 38: 127, 1988.
14. Hefni, M., and Witthöft, C. M. Effect of germination and subsequent oven-drying on folate content in different wheat and rye cultivars. J. Cereal Sci. 56:374, 2012.
15. Heiniö, R. L., Liukkonen, K. H., Katina, K., Myllymäki, O., and Poutanen, K. Milling fractionation of rye produces different sensory profiles of both flour and bread. LWT Food Sci. Technol. 36: 577, 2003.
16. Heiniö, R. L., Oksman-Caldentey, K. M., Latva-Kala, K., Lehtinen, P., and Poutanen, K. Effect of drying treatment conditions on sensory profile of germinated oat. Cereal Chem. 78:707, 2001.
17. Hemalatha, S., Platel, K., and Srinivasan, K. Influence of germination and fermentation on bioaccessibility of zinc and iron from food grains. Eur. J. Clin. Nutr. 61:342, 2007.
18. Hung, P. V., Maeda, T., Yamamoto, S., and Morita, N. Effects of germination on nutritional composition of waxy wheat. J. Sci. Food Agri. 92:667, 2012.
19. Jood, S., and Kapoor, A. C. Improvement in bioavailability of minerals of chickpea and blackgram cultivars through processing and cooking methods. Int. J. Food Sci. Nutr. 48:307, 1997.
20. Kariluoto, S., Liukkonen, K.-H., Myllymäki, O., Vahteristo, L., Kaukovirta-Norja, A., and Piironen, V. Effect of germination and thermal treatments on folates in rye. J. Agric. Food Chem. 54:9522, 2006.
21. Katina, K., Liukkonen, K.-H., Kaukovirta-Norja, A., Adlercreutz, H., Heinonen, S.-M., Lampi, A.-M., Pihlava, J.-M., and Poutanen, K. Fermentation-induced changes in the nutritional value of native or germinated rye. J. Cereal Sci. 46:348, 2007.
22. Koehler, P., Hartmann, G., Wieser, H., and Rychlik, M. Changes of folates, dietary fiber, and proteins in wheat as affected by germination. J. Agric. Food Chem. 55:4678, 2007.
23. Kunze, W., and Manger, H. J. *Technology Brewing and Malting*. VLB, Berlin, pages 493-494, 2004.
24. Larsson, M., Rossander-Hulthén, L., Sandström, B., and Sandberg, A.-S. Improved zinc and iron absorption from breakfast meals containing malted oats with reduced phytate content. Br. J. Nutr. 76:677, 1996.
25. Larsson, M., and Sandberg, A.-S. Phytate reduction in oats during malting. J. Food Sci. 57:994, 1992.
26. Makokha, A. O., Oniang'o, R. K., Njoroge, S. M., and Kamar, O. K. Effect of traditional fermentation and malting on phytic acid and mineral availability from sorghum (*Sorghum bicolor*) and finger millet (*Eleusine coracana*) grain varieties grown in Kenya. Food Nutr. Bull. 23(Suppl. 3):241, 2002.
27. Mbithi-Mwikya, S., Van Camp, J., Yiru, Y., and Huyghebaert, A. Nutrient and antinutrient changes in finger millet (*Eleusine coracan*) during sprouting. LWT-Food Sci. Technol. 33:9, 2000.
28. Nelson, K., Stojanovska, L., Vasiljevic, T., and Mathai, M. Germinated grains: A superior whole grain functional food? Can. J. Physiol. Pharmacol. 91:429, 2013.
29. Nonogaki, H., Bassel, G. W., and Bewley, J. D. Germination still a mystery. Plant Sci. 179:574, 2010.
30. Özcan, M. M., and Al Juhaimi, F. Effect of sprouting and roasting processes on some physico-chemical properties and mineral contents of soybean seed and oils. Food Chem. 154:337, 2014.
31. Plaza, L., de Ancos, B., and Cano, P. M. Nutritional and health-related compounds in sprouts and seeds of soybean (*Glycine max*), wheat (*Triticum aestivum* L.) and alfalfa (*Medicago sativa*) treated by a new drying method. Eur. Food Res. Technol. 216:138, 2003.
32. Przybylski, R., and Kamiński, E. Thermal degradation of precursors and formation of flavour compounds during heating of cereal products. Part II. The formation and changes of volatile flavour compounds in thermally treated malt extracts at different temperature and pH. Mol. Nutr. Food Res. 27:487, 1983.
33. Shurtleff, W., and Aoyagi, A. *Clive M. McCay and Jeanette B. McCay—History of Work with Soyfoods, the New York State Emergency Food Commission, Improved Bread, and Extension of Lifespan (1927-2009)*. Soyinfo Center, Lafayette, CA, 2009.
34. Suma, P. F., and Urooj, A. Influence of germination on bioaccessible iron and calcium in pearl millet (*Pennisetum typhoideum*). J. Food Sci. Technol. 51:976, 2014.
35. Tatala, S., Ndossi, G., Ash, D., and Mamiro, P. Effect of germination of finger millet on nutritional value of foods and effect of food supplement on nutrition and anaemia status in Tanzania children. Tanzania J. Health Res. 9:77, 2007.
36. Tizazu, S., Urga, K., Belay, A., Abuye, C., and Retta, N. Effect of germination on mineral bioavailability of sorghum-based complementary foods. Afr. J. Food Agric. Nutr. Dev. 11:5083, 2011.
37. Wai, K. N. T., Bishop, J. C., Mack, P. B., and Cotton, R. H. The vitamin content of soybeans and soybean sprouts as a function of germination time. Plant Physiol. 22:117, 1947.
38. Xu, M.-J., Dong, J.-F., and Zhu, M.-Y. Effects of germination conditions on ascorbic acid level and yield of soybean sprouts. J. Sci. Food Agric. 85:943, 2005.
39. Yang, T. K., Basu, B., and Ooraikul, F. Studies on germination conditions and antioxidant contents of wheat grain. Int. J. Food Sci. Nutr. 52:319, 2001.

Jennifer Pagand is R&D and innovation manager for the business unit Bakery Mixes at Puratos. Located at the Puratos headquarters in Belgium, she works on developing, in collaboration with the Marketing Department, innovative products and concepts for the grains and seeds breads category that can be positioned as healthy or nutritious. She also provides technical support to Puratos subsidiaries worldwide. Jennifer graduated with a master's degree in food science and food technology from ENSAIA (Nancy, France), an engineering school specializing in the food industry. Jennifer is the Puratos representative at the Healthgrain Forum and can be contacted at jpagand@puratos.com.

Pieter Heirbaut is R&D manager, processed grains, at Puratos. He is part of the business category processed grains and focuses on projects related to tender grains, seeds, and sprouts used mainly for bread applications. Pieter provides worldwide R&D support to Puratos subsidiaries that produce tender grain products. He is also involved in more fundamental research projects related to sprouted grains and works on new product development. Pieter obtained a master's degree in bioscience engineering from Ghent University in food science and nutrition and a major in food technology. Pieter can be contacted at pheirbaut@puratos.com.

Adeline Pierre is nutrition R&D manager and works in the Group Research & Services Lab at Puratos headquarters in Belgium. In addition to participating in defining the strategy for the company, she provides nutritional and regulatory support for product development and communication on the Puratos product focus groups, such as grains and seeds. Throughout her career Adeline has delivered bibliographic studies and state-of-the-art reviews on various nutrition- and health-related topics and participated in elaboration of clinical studies. Adeline obtained a master's degree in nutrition, health and food from the Institut Polytechnique LaSalle de Beauvais, France. Adeline can be contacted at apierre@puratos.com.

Bram Pareyt is research manager proteins for the Group Research & Services Lab in the Puratos Group headquarters in Belgium. Within the corporate lab, he is involved in fundamental research projects focusing on protein functionality, both in-house and in collaboration with Puratos' partners, as well as in projects more directly supporting different Puratos business units. Because of his background in cereal science, Bram is also involved in projects focusing on flour. He obtained his Ph.D. degree in bioengineering from KU Leuven (Belgium). Bram is an AACCI member and can be reached at bpareyt@puratos.com.