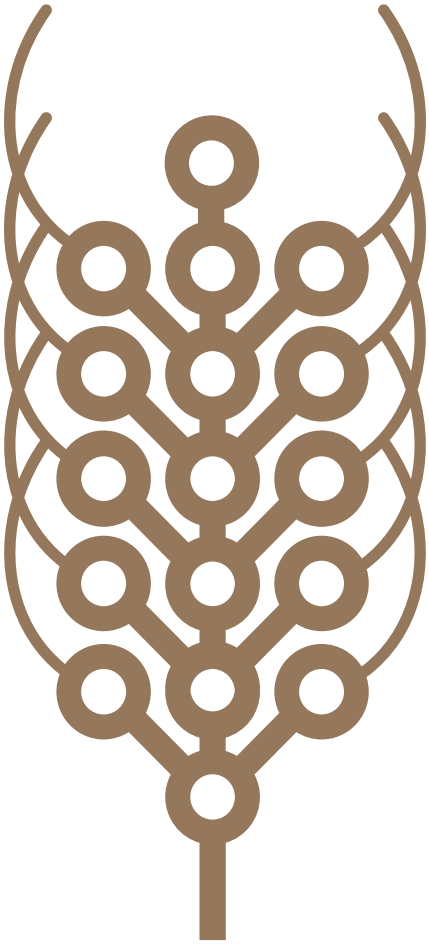
BARLEY+

RESISTANT STARCH AND PREBIOTIC FIBRE FOR GUT HEALTH AND THE MICROBIOTA



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Making food better

Barley+ is produced using the unique BARLEYmax™ whole grain

The Barley+ Muesli and Muesli Bar product range contains the whole grain BARLEYmax™ as its key ingredient. BARLEYmax™ is a new hull-less, whole grain barley cultivar, developed by Australia's CSIRO as part of their research into grains with higher fibre content and enhanced nutritional benefits. Due to its exceptional nutrition density and potential to positively influence human health, the CSIRO has a long-held interest in barley. BARLEYmax™ emerged from research stemming back to the 1990s, when amongst a collection of new non-genetically modified barley grains, BARLEYmax™ was identified as a superior cultivar, due to its high levels of dietary fibre including resistant starch (for its prebiotic activity), soluble fibres (incl. beta-glucan in high amounts) and insoluble fibres (cellulose, lignin) compared with other conventionally consumed whole grains (Figure 1) [1-3].

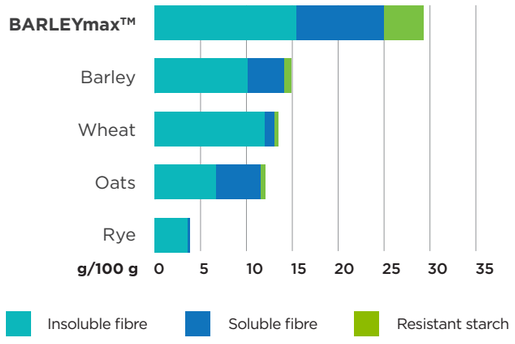


Figure 1: Resistant starch, soluble and insoluble fibre levels in BARLEYmax™ compared to other common whole grains [1].

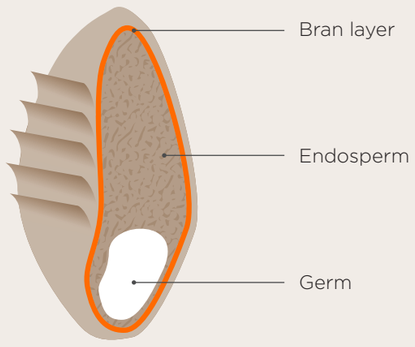
Australians do not meet recommended intakes of whole grains

The 2013 Australian Dietary Guidelines recommend Australian adults consume at least 4 to 6 serves of grain (cereal) foods per day, with at least two-thirds of grain products to come from wholegrain and/or higher cereal fibre varieties [8]. For 2–8 year old children, the recommended intake is 4 serves a day, which increases to 7 a day for older adolescents. Only 30% of Australians meet the recommended intakes [9].

Unfortunately, of the grain (cereal) foods Australians are eating, two-thirds are in the form of refined grains rather than whole grain or high fibre sources [9]. This means Australians are missing out on health benefits derived from the different fibre types that are naturally present in whole grains. Interestingly, children less than 3 years of age and adults aged 70 and over have the highest daily intakes.

One 50 gram serve of Barley+ Muesli adds nearly 2 serves of whole grains to a daily intake and so Barley+ can help Australians meet their recommended intakes of whole grain foods.

Barley kernel



Adequate consumption of whole grains is a well-accepted dietary pattern associated with reduced risk of chronic disease [4,5]. The benefits come from whole grain foods but not refined foods [6], which emphasises the importance of consuming whole grains like BARLEYmax™.
Food Standards Australia New Zealand defines a whole grain as the *"intact grain or the dehulled, ground, milled, cracked or flaked grain where the constituents—endosperm, germ and bran—are present in such proportions that represent the typical ratio of those fractions occurring in the whole cereal..."* [7]. Refined grains typically lose at least part of their whole grain integrity and consequently, part of their nutrition value.

Defining prebiotic dietary fibre, its effects on gastrointestinal microbiota and probiotic ingredients

Dietary **prebiotics** are defined as *"selectively fermented ingredients that result in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health"* [10, 11]. Examples of foods rich in dietary prebiotic fibres include Barley+, legumes and lentils, Jerusalem artichokes, onions, garlic, leek and asparagus [12]. Dietary prebiotics essentially provide substrate for the gut microbiota and subsequently can change the composition and activity of the resident gut microbiota [12, 13].

In contrast, **probiotics** are defined as *"live microorganisms which when administered in adequate amounts, confer a health benefit on the host"* [14]. Probiotics are essentially living microorganisms already present in fermented foods such as yogurt, kefir, miso, sauerkraut or kimchi, or as ingredients added to functional foods and dietary supplements. However, many probiotic commercial products contain bacteria species (bifidobacteria and lactobacilli), which are dominant species in milk-fed infants, but are relatively minor species in adults [13, 15]. It has been suggested that for effective use of probiotics, particular strains or species should target specific conditions [13].

The favourable influence of good dietary prebiotic intake on gut microbiota may be a better route to a healthier gut profile in some people. This may be especially relevant when specific probiotics are used in individual condition management.

Prebiotic dietary fibre: large bowel fermentation and effects on gut microbiota

The idea that fermentable food nutrients modulate the gastrointestinal microbiota existed long before formal definitions for such things existed [16]. Today, fermentable dietary nutrients or prebiotic dietary fibres are captured in the Food Standards Australia New Zealand's (FSANZ) definition of dietary fibre as *"that fraction of the edible parts of plants or their extracts, or synthetic analogues, that are resistant to digestion and absorption in the small intestine, usually with complete or partial fermentation in the large intestine.*

Gastrointestinal microbiota, diet and disease

The gastrointestinal tract is inhabited by vast and diverse populations of microorganisms, with the largest and most important found in the colon [11, 17]. Over one trillion bacteria contribute to the makeup the human gut microbiota, and play a fundamental role in the wellbeing of the host [17-19]. The constituents of the microbiota have been shown to interact with one another and with the host immune system in ways that influence the development of disease [17, 20-22]. For instance, changes in the intestinal microbiota can disrupt normal intestinal function [20], irritable bowel disease pathogenesis is linked to the gastrointestinal microbiota [17, 23] and some [24, 25] but not all [26] studies show that obesity is associated with an imbalance in normal gut microbiota. The importance of the link between dietary intake, colonic microorganism metabolism and human health is becoming increasingly well recognised [13, 21, 27], and may at least partly explain the relationship between the protective effects of specific dietary fibre types and serious chronic diseases, including colorectal cancer [18, 28, 29].

Dietary fibre includes polysaccharides, oligosaccharides and lignins and promotes one or more of the following beneficial physiological effects:
1) laxation;
2) modulation of blood glucose; and
3) reduction in blood cholesterol" [7].

Gut microbiota: typical bacteria profile

The bacterial composition of the gut microbiota varies considerably between healthy individuals, depending on their diet and other environmental factors [17]. However, it has been shown that bacteria of the bacteroidetes and firmicutes phyla typically dominate the gut bacteria communities [17, 30].

Further, it is suggested that the microbiota profile of most adults can be classified into one of three 'types' or enterotypes, based on their particular dominant genera and their ratios to one another [17, 26].

Enterotype 1 is dominated by the bacteroides genera; enterotype 2 is dominated by the prevotella genera; and enterotype 3 is dominated by the ruminococcus genera [17, 26].

Interestingly, these broad gut microbiota enterotype patterns are largely determined by diet [17, 27].

Resistant starch prebiotic activity

In humans, one of the major functions of the large bowel microbiota is to produce short-chain fatty acids (SCFA), which supply energy to the intestinal cells of the host. Intake of fermentable prebiotic fibre can greatly alter microbiota profiles and increase specific bacteria numbers in the large bowel by providing substrate to gut bacteria or by increasing SCFA supply to other gut microbes and decreasing pH levels [31-34]. Insufficient SCFA supply limits substrate availability to gut microbiota and intestinal cells and is understood to be a determinant of poor gut health [34]. Resistant starch specifically has been shown in human and animal models to modify gut microbiota [35-38], and to promote beneficial effects on large bowel function in healthy adults [39]. As expected, the type and magnitude of response to resistant starch is highly variable between human individuals, is reversible and is tightly associated with resistant starch intake [38]. Recently, resistant starch has also been shown to improve insulin sensitivity independently of the gut microbiota in rodents, highlighting that resistant starch may also exert health effects via other metabolic pathways, such as alterations in the bile acid cycle [40]. Other well documented prebiotic effects in humans stem from fructans and fructooligosaccharides [41-43], which make up ~10% of BARLEYmax™ whole grains.

BARLEYmax™ prebiotic activity and a healthier gut microbiota

BARLEYmax™ and so Barley+ is a rich source of various prebiotic dietary nutrients, including resistant starch, fructans and fructooligosaccharides. It is the bacteria-generated SCFA metabolic end products of dietary nutrient fermentation that contribute significantly to human health [32, 44]. Butyrate, propionate and acetate are the bacteria-generated SCFAs of principal importance to colonic health [13, 19, 44] (Figure 3).

Butyrate is the preferred substrate for the cells in the colon and importantly, butyrate appears to promote a normal phenotype in these colon cells [32]. Resistant starch is the major substrate for colonic butyrate production [29, 39]. **Fermentation of BARLEYmax™ resistant starch and prebiotic nutrients has been shown to favour the production of the butyrate SCFA in the colon [45, 46].** It has also been suggested that butyrate has the strongest protective effect against colorectal cancer [29]. To this end, some experts suggest that the higher colorectal cancer rates observed in Australia relative to lower risk populations may be attributable to insufficient consumption of resistant starch and other more fermentable fibre types, while populations at lower risk consume higher levels of resistant starch and fermentable fibre via whole grain intakes and cooking practices [28, 44].

Fermentation of prebiotic nutrients

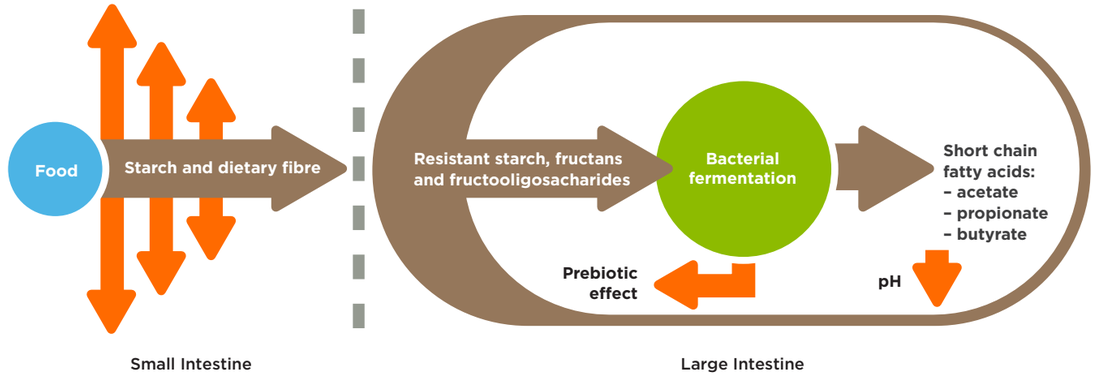


Figure 3: Fermentation of dietary prebiotic resistant starch, fructans and fructooligosaccharides and SCFA production in the large bowel. Lower pH values (and raised SCFA) are believed to prevent the overgrowth of pH-sensitive pathogenic bacteria [32]. Figure adapted from reference [32].

Importantly, it appears that observations of beneficial prebiotic properties of resistant starch to dietary modulation of colorectal cancer risk may be maximised with the combined consumption of insoluble fibre [47]. Consuming insoluble fibre and resistant starch together pushes the fermentation of resistant starch further distally in the colon, which subsequently improves conditions in the distal colonic regions where tumours most commonly occur [47]. **BARLEYmax™ has high levels of both resistant starch and insoluble fibre, compared with other conventionally consumed whole grains.**

While further human clinical studies are needed to elucidate the exact effects of resistant starch and prebiotic dietary fibre on gut microbiota shifts and consequent specific benefits, the following is well established:

- BARLEYmax™ is a non-genetically modified whole grain barley cultivar developed by Australia's CSIRO and contains more resistant starch, soluble fibre and insoluble fibre in the one whole grain versus other commercial grains;
- Adequate consumption of whole grains is a well-accepted dietary pattern associated with reduced risk of chronic disease [4, 5];
- BARLEYmax™, and so Barley+, provides a rich source of resistant starch and other fermentable nutrients with prebiotic effects;
- Dietary prebiotics result in specific changes in the composition and/or activity of the gastrointestinal microbiota and confer benefit(s) upon host health [10, 11];
- Resistant starch and fermentable dietary nutrients can modify gut microbiota [35-38] and promote beneficial effects on large bowel function in healthy adults [39];
- Fermentation of BARLEYmax™ resistant starch and prebiotic fibre has been shown to favour the production of the butyrate SCFA in the colon [45, 46]; butyrate is the preferred fuel for colon cells.

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