MAKING FOOD EXTRAORDINARY
TATE & LYLE
SINCE 1859

BETA GLUCAN: HEALTH BENEFITS AND PRODUCT APPLICATIONS

Innovating to Meet Nutrition, Health, and Wellness Needs Every Day

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PromOat® Beta Glucan

- Despite the fact that many consumers say that they are making efforts to consume diets high in dietary fibre, current fibre intakes remain low.
- Research indicates that diets higher in fibre are associated with improved health and reduced risk of certain diseases, including cardiovascular disease and diabetes.
- Oat beta glucan is a viscous, soluble fibre that can help maintain normal blood cholesterol and blood glucose levels, as well as support gastrointestinal health, and emerging evidence suggests it may assist in weight management.
- Tate & Lyle's PromOat® Beta Glucan is a great example of an ingredient that manufacturers can use in the development of new and innovative products that may promote health while helping to meet the population's dietary fibre needs.

FIBRE TYPES AND HEALTH BENEFITS

Decades of research point to the health benefits of fibre, including supporting cardiovascular health, tempering spikes in blood sugar, aiding weight management and promoting a healthy gut.[1-3] Yet, across the globe, average intakes are well below the recommended amount despite the widespread knowledge of fibre's role in a healthy diet.[3]

Dietary fibres are non-digestible carbohydrates in the diet that, when consumed, pass through the small intestine into the large intestine where they may be partially or completely fermented by colonic microbiota.[2] Fibres can be soluble or insoluble in water as well as viscous or non-viscous. Viscous soluble fibres, including oat beta glucan, are the only fibres that have been shown to lower cholesterol.[4] Research studies have demonstrated that increasing soluble fibre intake by 5-10 g/day can reduce LDL cholesterol by up to 5%.[5] For greater LDL cholesterol reductions, the National Heart, Lung, and Blood Institute's Therapeutic Lifestyle Changes (TLC) diet recommends soluble fibre intakes up to 25 g/day.[4] Considering that most individuals habitually consume less than 25 grams of fibre per day in total,[6-12] methods to increase soluble fibre intake are needed.

Tate & Lyle's PromOat® Beta Glucan is a viscous soluble fibre made from non-genetically modified (non-GM) Swedish oats that can be added to foods and beverages to promote normal cholesterol levels while increasing dietary fibre intake. Clinical studies have demonstrated additional health benefits associated with oat beta glucan intake, such as maintaining normal blood glucose levels, supporting gastrointestinal health, and emerging evidence suggests it may assist in weight management.

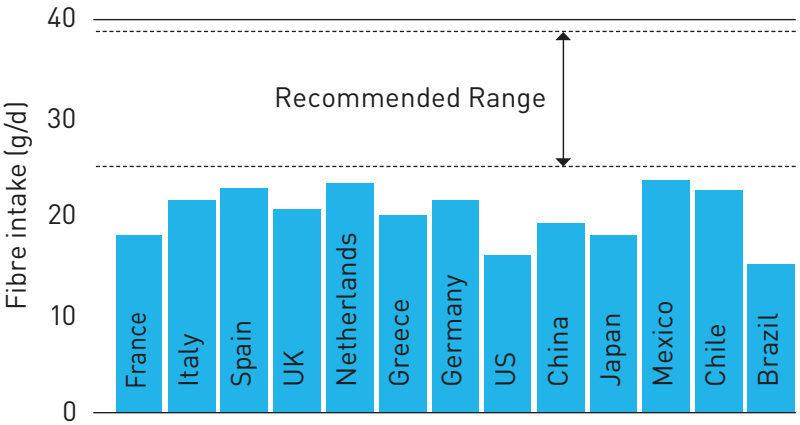
Dietary fibre gap: Intakes vs. recommendations

Recommendations for fibre intakes range from 25-38 g/day depending on country-specific guidelines.[2, 3] The World Health Organization (WHO) suggests worldwide consumption of greater than 25 g/day,[13] but fibre intakes in most countries are well below this level[6-12] [Figure1].

For example, in the United States (US), for most age and gender groups, 5% or fewer meet the dietary

Figure 1

Average adult fibre intakes by country[6-12]



HEALTH BENEFITS

Oat beta glucan has been tested by a number of independent researchers to demonstrate its physiological health benefits. The following are some highlights of the research on the health benefits of oat beta glucan:

- **Promotes heart health by lowering blood cholesterol levels[17, 18, 22, 23, 25]**
- **Supports normal blood glucose levels by eliciting a lower glycaemic response[19, 26, 27]**
- **Well tolerated and may support a healthy gut by producing short-chain fatty acids (SCFA)[39, 40, 44]**
- **May assist with weight management through calorie and fat reduction in foods and promotion of satiety[32-34]**

recommendations for fibre despite consistent messaging to the public to increase dietary fibre intake.[14, 15]

Survey data indicates that consumers believe fibre is one of the most important components of health,[16] yet closing the fibre intake gap has not been easy, as many diets continue to lack adequate servings of fruits, vegetables, whole grains, and fibre-fortified foods. Recent innovations are making it easier for food manufacturers to fortify their products to help boost fibre content and close this intake gap. An abundance of research continues to demonstrate that added fibres provide similar benefits as intact fibres inherent in whole foods.

Fibre innovation

While traditional sources of fibre like whole grains, fruits, and vegetables should be encouraged, added fibres are also important contributors to dietary fibre intake. Added fibres, also known as 'functional' fibres, are non-digestible carbohydrates that are isolated from a food source, or synthesized non-digestible carbohydrates, that have beneficial physiological effects in humans.[2]

These fibres can be extracted from one food source and added to another (e.g., bran added to grain-based foods); or they can be manufactured from grains like oat (e.g., PromOat® Beta Glucan), or from fruit, vegetables, legumes, nuts and seeds;[2] or the fibres can be modified forms of traditional fibres.[2] Adding fibre to new or commonly consumed foods is one strategy to increase the dietary fibre intake of target populations in order to bridge the gap between actual intakes and recommended intakes.

PromOat® Beta Glucan is an example of a versatile functional fibre ingredient produced by Tate & Lyle and currently used in foods and beverages in North America, Latin America, Europe, and Asia as a potential solution to increase fibre intake without sacrificing taste, texture, or enjoyment. Total daily intakes of beta glucan as low as 3.0-4.0 g/day have been shown to promote health through maintenance of normal blood cholesterol and blood glucose levels while helping to meet daily recommended fibre needs.[17, 18]

Characterization of PromOat® Beta Glucan

Beta glucans from oats and barley are polysaccharides of linear, mixed linkage (1,3), (1,4)-beta-D-glucans. PromOat® Beta Glucan is concentrated beta glucan derived from non-GM, Swedish oats, produced by a chemical-free, aqueous, enzymatic process. The final product is a fine, cream-colored powder with a caloric value of 3.2 kcal/g of ingredient.*

*Caloric labeling varies based on regional and country regulations.

PromOat® Beta Glucan is a source of as high as 34% oat soluble beta glucan fibre by weight, and contains carbohydrate, with relatively small amounts of fat and protein [Table 1].

Oat beta glucans from different sources can have a wide-range of molecular weights, as processing conditions affect the final product. PromOat® Beta Glucan has a high molecular weight similar to native oat beta glucan. The high molecular weight makes PromOat® Beta Glucan

Table 1
Nutritional content of PromOat® Beta Glucan[a] (typical values)

PromOat® Beta Glucan	
Energy[b]	323 kcal (1351 kJ)
Total Fat	6.5 g
Saturated Fat	1.2 g
Total Carbohydrate	82.5 g
Dietary fibre	40 g
Beta glucan fibre[c]	32 g
Other fibre	8 g
Sugars	2 g
Other Carbohydrate	40.5 g
Protein	3.5 g
Sodium	68 mg

[a] Values per 100 g on a dry weight basis.
[b] Determined by calculation using 2 kcal/g for the soluble fibre portion. When using 4 kcal/g for the soluble fibre portion, the calculated calorie value is 403 kcal.
[c] Typical range: 32-34 g.

highly viscous. Many health benefits associated with oat beta glucan are attributed to viscosity that increases with molecular weight.[17, 19, 20]

PromOat® Beta Glucan has strong water-binding and emulsifying properties. It thickens and stabilizes emulsions, creating a smooth texture and creamy mouth feel in reduced-fat products. This ingredient can also lengthen the shelf life of food products due to improved moisture management, and it is acid- and heat-stable, which allows for easy integration into many food and beverage products.

FIBRE INNOVATION FOR HEALTH

Supports normal blood cholesterol

In 2012, the World Health Organization reported that coronary heart disease (CHD) was the leading cause of mortality, resulting in 7.6 million deaths worldwide.[21] It is well-established that reducing blood cholesterol reduces the risk of CHD, and the US National Cholesterol Education Program (NCEP)* estimates that each 1% reduction in LDL cholesterol reduces the risk of heart disease by 1-2%.[5]

Many clinical studies have demonstrated that increasing intake of viscous soluble fibres like beta glucan can effectively reduce LDL and total cholesterol. Three meta-analyses have summarized nearly 50 randomized controlled trials including 1,780 normo- and hypercholesterolaemic subjects completed between 1985 to 2007.[22-24] Overall, the data suggest that 3 g/day of beta glucan can lower LDL cholesterol by 3-5% and total cholesterol by 2-4%.[22-24] This may result in a reduction in heart disease by 3-10%, with the greatest reductions occurring in those with higher starting cholesterol levels.[22] Additionally, the physicochemical properties of beta glucans can impact the efficacy in lowering cholesterol. Oat beta glucans with high molecular weight and solubility used at high concentrations are thought to be more viscous in the small intestine. This increased viscosity may reduce reabsorption of bile acids and increase the synthesis of new bile acids from cholesterol, thus reducing circulating LDL concentrations.[18]

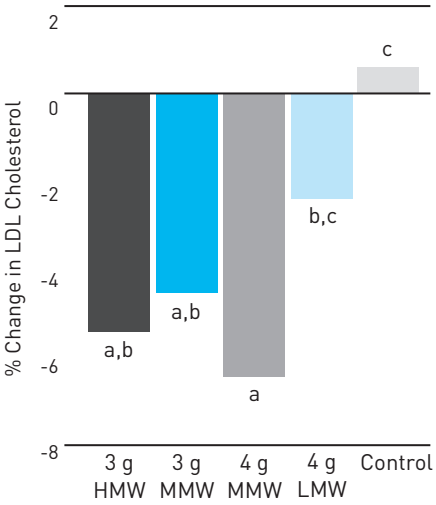
In weighing the totality of the evidence, the European Food Safety Authority (EFSA) issued a positive opinion for the ability of oat beta glucans to lower blood cholesterol and reduce the risk of cardiovascular disease.[18] Several countries allow health claims or functional claims for beta glucan and heart health/cholesterol reduction. The claims are based on a daily consumption of 3 g beta glucan, which in most cases can be divided among three to four servings of foods.

Recent studies continue to support the findings that oat beta glucan may promote the reduction of blood cholesterol. For example, Queenan *et al* demonstrated that 6 g/day of oat beta glucan significantly reduced LDL cholesterol in those with elevated cholesterol compared to a control.[25] Further, Wolever *et al* demonstrated that both oat beta glucan dose and molecular weight are critical in cholesterol lowering.[17] In this study, 3 g/day of a high molecular weight and 3 g/day and 4 g/day of a medium molecular weight oat beta glucan significantly reduced LDL cholesterol compared to a wheat fibre control [Figure 2].[17] PromOat® Beta Glucan is a high molecular weight beta glucan.

Favorable blood glucose and insulin response

The impact of oat beta glucan on blood glucose and insulin responses has also been studied extensively over the past few decades. In 2011, EFSA determined that a cause and effect relationship has been established between the consumption of beta glucans (from both oat and barley sources) and a reduction of postprandial glycaemic responses.[26] Their conclusion was based on results of six key clinical trials that consistently demonstrated an effect of oat and barley beta glucans in decreasing postprandial glycaemic responses, without disproportionately increasing postprandial insulinaemic responses, at doses of at least 4 g per 30 g of available carbohydrates.[26] Further, EFSA determined that the mechanism by which beta glucans lower blood glucose has been well

Figure 2
Reduction in LDL cholesterol following four weeks of oat beta glucan consumption[17]



Treatment groups with different letters are significantly different (P<0.05)
HMW=High molecular weight
MMW=Medium molecular weight
LMW=Low molecular weight

*A program managed by the US National Institutes of Health

Diets high in fibre have been associated with lower risk of heart disease and improved blood glucose levels while also supporting digestive health and laxation and potentially aiding in weight management.

established.[26] Beta glucans increase the viscosity of the meal bolus, thereby reducing the interaction between food and digestive enzymes in the stomach, delaying gastric emptying, and reducing absorption of glucose.[26-30] Because viscosity plays a large role in reducing blood glucose and insulin responses, differences in physicochemical properties of beta glucans, such as molecular weight, may impact the magnitude of the effect.

A recent review by Tosh concluded that the EFSA recommendation of including 4 g of beta glucan per 30 g available carbohydrate may be too restrictive.[27] A total of 34 studies with 119 treatments including both oat and barley beta glucan were included in this review. These studies were controlled, randomized, blinded, crossover, or parallel in design and included information on available carbohydrate dose, beta glucan dose, and postprandial blood glucose response. Data were combined for oat and barley products as average reductions in area under the curve (AUC) for glycaemic response were not significantly different. Tosh found that glycaemic response was more strongly related to beta glucan dose than the ratio of beta glucan to available carbohydrate in processed foods. Including at least 4 g beta glucan per ~30-80 g of available carbohydrate should significantly reduce postprandial glycaemic response.[27]

Studies published after these reviews continue to provide evidence that beta glucan can reduce postprandial glycaemic response and that the physicochemical properties of the beta glucan consumed may impact the magnitude of the results. For example, Kwong *et al* demonstrated that at a dose of 4 g, a high molecular weight, high viscosity beta glucan was more effective at attenuating peak blood glucose rise than a low molecular weight, lower viscosity beta glucan.[19] Hartvigsen *et al* studied PromOat® Beta Glucan in a randomized, cross-over intervention in 15 subjects with metabolic syndrome to assess the effects of 4.2 g beta glucan within bread delivering 50 g of digestible carbohydrate on blood glucose and insulin response. The beta glucan-containing bread induced a significantly lower blood glucose response compared to the control bread, but there were no differences in insulin response. The effect on lowering blood glucose response is likely due to the increased intestinal viscosity from the beta glucan resulting in reduced rate of absorption and subsequent glucose response. The lack of significance in the insulin response is likely due to the large variations in these metabolic syndrome subjects.[31] While these studies indicate that beta glucan can lower acute blood glucose response, longer term studies on beta glucan's effect on blood glucose in those with metabolic syndrome and diabetes are warranted.

Weight management

PromOat® Beta Glucan may help support weight management through enabling fat and calorie reduction in food formulations. Emerging evidence suggests that intake of beta glucan may also promote satiety and/or reduced energy intake at a subsequent meal. For example, Beck *et al* [32, 33] observed that subjective satiety ratings significantly increased with an oat beta glucan dose as low as 2.2 g and that appetite suppressant hormones cholecystokinin (CCK) and plasma peptide YY (PYY) were significantly increased in a dose-dependent manner when evaluating 0 g (control), 2.2 g, 3.8 g, and 5.5 g of beta glucan for part or all of the study population. Energy intake at a subsequent meal was also reduced in subjects who consumed the highest dose of beta glucan compared to the control. Although these energy intake results did not reach statistical significance, the absolute difference was greater than 400 kJ (~95 kcal) in a single meal, which is clinically relevant as it could equate to a 0.4 kg (0.9 lb) weight loss monthly if maintained.[33]

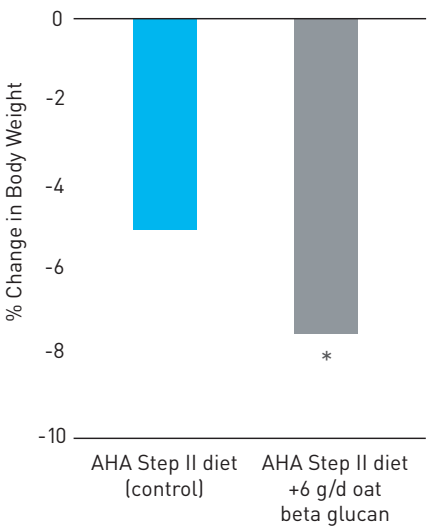
A study using PromOat® Beta Glucan at 4.2 g beta glucan reported subjective measures of satiety increased significantly but there was no significant impact on energy intake at a subsequent meal in subjects with metabolic syndrome.[31] Chronic studies provide a better indication of the long-term effects of oat beta glucan on

Emerging evidence suggests that oat beta glucan may support weight management efforts through increased satiety, changes in satiety hormones, and reduced calorie intake.

satiety and weight management. In a randomized, controlled, parallel-group study of an oat-derived beta glucan extract, thirty-eight overweight men consumed the TLC/Step II diet** for eight weeks and bread with 6 g of beta glucan or a whole-wheat bread control.[34] The two breads were equivalent in energy, protein, fat, and carbohydrate, and energy intakes between the groups were similar overall. Both body weight and body mass index (BMI) were reduced by 7.5% in the oat beta glucan group and 4.9% in the control group, resulting in a statistically significant difference between the two groups [Figure 3].[34]

While additional studies are needed, this emerging evidence suggests that oat beta glucan may support weight management efforts through increased satiety, changes in satiety hormones, and reduced calorie intake.

Figure 3
Reduction in body weight after 6 g/day oat beta glucan for eight weeks[34]



*Significant difference compared to control (P<0.002)

Promotes gastrointestinal health

RESISTS DIGESTION AND IS FERMENTED IN THE GUT

Oat beta glucan contains a mixture of ß (1-3) and ß (1-4) glucosidic linkages that reduce the digestibility of this ingredient.[35-38] Undigested beta glucan serves as a valuable substrate for fermentation by colonic bacteria, leading to the production of the SCFA propionate, butyrate, and acetate.

In vitro studies demonstrate that significantly greater production of butyrate occurs with fermentation of beta glucan compared to inulin,[39] FOS, psyllium, and corn arabinoxylan.[40] Increasing butyrate is desirable as it is the main energy source for colonocytes and has demonstrated anti-inflammatory and anticarcinogenic properties.[41, 42] Propionate production was also enhanced in these studies,[39, 40] which may be beneficial due to links between this SCFA and satiety as well as inhibition of cholesterol synthesis.[42, 43] Fermentation of oat beta glucan has also been demonstrated in rats. Over a six-week period, faecal pH was reduced and SCFA concentrations were increased in rats fed oat beta glucan. Additionally, ammonia levels, ß-glucuronidase activity, and azoreductase activity were reduced, suggesting that consumption of oat beta glucan may reduce the concentration of toxic compounds in the colon.[44] Compared to many other fibres, the fermentation of oat beta glucan is delayed, occurring in the distal colon, which may further promote colonic health by enhancing production of beneficial SCFA in the distal colon where toxic compounds from protein digestion are created and the majority of colon cancer lesions are seen,[25, 40, 45] however, additional research is needed.

Good digestive tolerance

Oat beta glucan is a well-tolerated soluble fibre. The majority of studies investigating the various health benefits of oat beta glucan have been completed without reports of gastrointestinal disturbances.

USE OF PROMOAT® BETA GLUCAN IN FOODS AND BEVERAGES

PromOat® Beta Glucan can be used in a wide-variety of foods and beverages including cereals, baked goods, soups, sauces, salad dressings, dips, smoothies, fruit juices, and sports drinks. Its contribution to the product's overall fibre may be included in the fibre listing on the nutrition information panel for food.

Average fibre intakes globally fall well below recommended intake

** The TLC/Step II diet is recommend by the US NCEP and the American Heart Association for individuals with elevated blood cholesterol. The diet is reduced in fat, saturated fat, and cholesterol compared to a typical western diet.

To learn more about Tate & Lyle ingredients and innovations as well as health benefits and relevant research, please visit www.foodnutritionknowledge.info and www.tateandlyle.com.

Tate & Lyle's Global Commercial and Food Innovation Center, Hoffman Estates, Illinois, USA

levels,[6-12] yet diets high in fibre have been associated with lower risk of heart disease and improved blood glucose levels while also supporting digestive health and laxation and potentially aiding in weight management.[1-3]

Consumption of foods and beverages made with PromOat® Beta Glucan can help close the fibre intake gap and may help to reduce calorie and fat intake. PromOat® Beta Glucan is well-tolerated, and research suggests that it supports normal cholesterol and blood glucose levels, may promote gastrointestinal health, and may potentially aid in weight maintenance.

INNOVATING TO MEET NUTRITION, HEALTH, AND WELLNESS NEEDS EVERY DAY

Nutrition professionals' opportunity to educate consumers

While many people acknowledge the added health benefits of fibre, only 25% of consumers around the world report daily consumption of fibre.[46] Consumers want to consume more products with fibre, but struggle to find them. In fact, 33% of consumers claim they are not eating more fibre because not enough products with fibre are available on the market.[46]

Adding small amounts of fibre to foods that contain some dietary fibre or to foods traditionally low in dietary fibre could help individuals meet their fibre requirements without exceeding calories, which is a practical way to help address global public health concerns.[47] Nutrition professionals can help to move consumers toward the goal of increasing fibre intake with education on benefits and sources of dietary fibre as consumers desire to make dietary changes.

CONCLUSIONS

While individuals should increase their consumption of dietary fibre from sources such as beans and peas, other vegetables, fruits, and whole grains,[1] the incorporation of added fibre like PromOat® Beta Glucan into foods as part of a well-balanced diet can help close the intake gap between recommended and actual intakes. As a gently processed, high molecular weight, neutral tasting beta glucan, Tate & Lyle's PromOat® Beta Glucan is uniquely positioned to be an ingredient that food manufacturers can use in the development of new and innovative products to meet the population's fibre needs. Oat beta-glucan also provides health benefits, including maintenance of normal blood cholesterol and blood glucose, supporting gastrointestinal health, and potentially supporting weight management.

A commitment to innovation

Tate & Lyle, a global leader in wellness innovation, is committed to delivering innovative ingredients that can be incorporated into great-tasting foods to help consumers meet their nutrition, health, and wellness needs every day. That is because Tate & Lyle invests heavily in innovation and research and in developing ingredients that can be incorporated into a wide-variety of food and beverage solutions. Teams of food and nutrition scientists are continuously innovating, researching, and testing ingredients that will meet current and future health and nutrition needs.

At the same time, Tate & Lyle has a robust market research program designed to provide the necessary insights on consumer preferences around the world. The research program allows Tate & Lyle to customize its offerings and provide tailor-made solutions in local and regional markets.

Better-for-you ingredients for health and wellness

In response to global public health efforts calling for people to reduce calories and sodium and increase fibre intakes, Tate & Lyle offers a number of novel ingredient solutions that meet these needs.

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