at (Avena sativa L.) is a typical northern cereal. As such, it prefers a wet, cold climate with rain during the growing phase and sunshine and long hours of daylight during the harvest season. For approximately 2000 years, oats and barley were staples of the diet in Nordic countries. Only at the beginning of the 19th century were oats partially replaced by other cereals and potatoes. The greatest virtue of oats is its 100% naturalness – the only grain not affected by the controversy around GMOs, and that the benefits are many. Oats not only contain the beta-glucans but also antioxidants, plant sterols, proteins and polyunsaturated fatty acids. Today, interest in oats is increasing, and it retains a strong image as a nutritious, health-promoting ingredient in food applications due to its high bioactive and functional component contents.

Significant positive health effects have been attributed to oat products, including cholesterol control, modulation of glucose and insulin responses, weight management, and improved gastrointestinal function. Probably the most well-recognized health-promoting ingredient from oats is β-glucan, a soluble fiber. Most consumers today are aware of proven and advanced nutrition and the specific benefits they provide in improving wellbeing and lowering risk factors for diseases such as coronary heart disease. The approvals in Finland and the Netherlands and UK of health claims for oat beta-glucans is expected to stimulate NPD activity and begin to lower the door to a Europe-wide health claim.

Chemistry of oat β-glucans

Oat β-glucans are nonstarch polysaccharides. Like starch, they are composed of glucose molecules in long chains, but the binding between glucose monomers differs from starch. In starch, the glucose monomers are connected by α-bonds: amylose has α-(1→4) bonds, whereas amylpectin, in addition to long glucose chains with α-(1→4) bonds, also has α-(1→6) bonds that initiate side chains. The two α-bonds in starch are easily digested by enzymes in the intestine.

Cellulose is also a polysaccharide and is composed of long chains of glucose molecules bound by β-(1→4) which produces a straight molecule. The intestine does not contain enzymes that can digest these β-(1→4) links. Cellulose is not a non-soluble fiber because the long, straight chains are closely packed and water molecules cannot penetrate and dissolve the fibers.

Our β-glucans, like cellulose, are linear glucose polymers, but oat β-glucans have both β-(1→4) and β-(1→3) links, creating a cellulose chain with both β-(1→4) and β-(1→3) links interrupted by β-(1→3)-linked glucose units. Approximately 70% of the links are β-(1→4), and the rest are β-(1→3). The distribution is not random: the β-(1→3) linkages always occur singly and most of the β-(1→4) linkages in groups of three or four. The intestine does not contain enzymes that can digest these β-(1→3) links, so they are by definition a fiber. The mixed linkages that form oat β-glucans are important for their physical properties, such as viscosity and solubility. The presence of two types of linkages prevents compact folding of oat β-glucan chains, making them soluble in water. The (1→3)-linked residues result in links in the otherwise ribbon-like shape of the molecule, allowing water to penetrate and solubilize the fiber. The longer (1→4) sequences are believed to be responsible for the partial water insolubility properties of oat β-glucans, because they provide surfaces that are capable of forming junction zones.

Oat β-glucans are asymmetric molecules that assume an extended conformation in aqueous solution, best described as worm-like chains. One theoretical model describes β-glucans in solution as an extended random coil.

Oat β-glucans are large molecules. Available data on molecular weight distribution vary between 2684 × 10^4 and 3 × 10^6 g/mol. These variations probably depend on differences in raw materials, processing, and methods of determination. Even at low concentrations in water solutions, oat β-glucan molecules interact, causing marked resistance in water flow and creating a viscous solution. If the concentration is high enough, a gel is formed through associations between molecules.

Increased viscosity is a fundamental characteristic of oat β-glucan solutions and has an important impact on their physiological behavior in the intestine and, thus, their physiological function. Viscosity plays an important role in cholesterol-lowering effects and not only on the glycaemic response. Solubilisation and the molecular weight of β-glucans influence viscosity and bioavailability. Viscosity is mainly determined by molecular weight, but also by molecular structure, resulting from the distribution of β-(1→3) and (1→4) links. In conclusion, to maintain functional attributes, food containing oat β-glucan must be controlled during processing and in food matrices. The physiological effects of oat β-glucan glucan depend at least in part on the viscosity and not only on the amount of β-glucans. Therefore, it is critical not only to know the β-glucan concentration, but also the solubility, viscosity, and molecular weight of β-glucans in the product.

Fig. 1. Molecular weight (MW) and solubility of β-glucans extracted by digestive enzymes at 37°C and hot water from OatWell® oat bran / commercially available oat products / oat bran, and rolled oats. *, Data from Beer and coworkers (6); **, MW and solubility 10^4 g/mol 10^5 10^6. Even at low concentrations in water solutions, oat β-glucan molecules interact, causing marked resistance in water flow and creating a viscous solution. If the concentration is high enough, a gel is formed through associations between molecules.

Fig. 2. Apparent viscosity of soluble fiber extract physiological 37°C after in vitro digestion from OatWell® oat bran and commercially available oat products at increasing β-glucan concentration in the extract.
are digested and absorbed very rapidly from the intestine into the blood stream, causing a high glycemic response or glycemic index (GI) and rapid secretion of insulin from the pancreas. Increased insulin levels are believed to be a key factor in the development of several diseases. Studies show positive metabolic effects of diets containing carbohydrates that are slowly digested in the intestine and have a low GI. Epidemiological data suggest that a low-GI diet may help prevent type II diabetes and cardiovascular disease, and metabolic syndrome, but the course of events causing the effect is not fully understood. One hypothesis is that in the intestine food is “incorporated” into the viscous oat ß-glucan solution making it more difficult for enzymes in the intestine to degrade the food components and causing digestion to take longer. Another hypothesis is that oat ß-glucans form a protective layer along the intestinal wall that acts as a viscous barrier slowing food uptake from the intestine.

### Blood cholesterol and oat ß-glucans

Substantial clinical evidence from the last 40 years has documented that oat ß-glucans have an effect on blood cholesterol levels and control of lipoprotein metabolism. At the level of statistical significance, biological relevance can be attached to very small changes in a marker. This is exemplified by reference to blood cholesterol levels of total (LDL, cholesterol, HDL, cholesterol) in which at the population level, a few percent change has large implications on the risk of coronary heart disease. Oat ß-glucans are believed to favorably affect blood cholesterol and lipoprotein metabolism mainly by increasing viscosity in the small intestine.

There are different theories concerning the mechanisms of the blood cholesterol lowering effect of oat ß-glucans. One theory proposes that the viscous oat ß-glucans engulf bile acids, resulting in their excretion in the feces. Bile acids generally are recycled, i.e., they are taken up in the lower part of the intestine and used again. Through excretion in feces, the body loses bile acids and has to synthesize new ones, which is done in the liver. The building block for bile acids is cholesterol, which the liver extracts from the blood, decreasing blood cholesterol levels. Another hypothesis is that fermentation of soluble fiber by bacteria in the large intestine produces propionate. The propionate is then absorbed by the colon cells and goes to the liver where it is thought to have an effect on cholesterol synthesis. A third theory is that oat ß-glucans interfere with the absorption of lipids, probably by reducing or delaying the emulsification and lipid hydrolysis process.

### Oat ß-glucans as prebiotics

The lower part of the intestine, the colon, has been identified as a key organ affecting general health. The growth and metabolism of the many individual bacterial species inhabiting the colon depend primarily on the substrates available to them, most of which come from the diet. Oat ß-glucans, which are indigestible in the small intestine but are fermented by bacteria in the colon, are prebiotics. Prebiotics are non-digestible food ingredients that selectively stimulate the growth or activities of bacteria in the colon. They beneficially affect a series of intestinal functions by modulating the structure, composition, and metabolic activity of mucosa and microflora in the colon. The end products created from prebiotic fermentation in the colon are short-chain fatty acids, e.g., butyric acid, that serve as nutrients for mucosal cells.

### OatWell® oat bran

High-quality oats are grown in Scandinavia and Canada. Highly selective processing controls are used to produce natural, consistent OatWell® oat bran ingredients with high total dietary fiber (44%) and ß-glucan (up to 22%) contents. To maintain functional attributes, it is important that the processing of oat kernels into oat bran, which has an elevated concentration of ß-glucans, does not destroy the ß-glucan structure. The level of oat ß-glucans is significantly higher compared with other oat and oat bran products. Viscosity, solubility and molecular weight are important production control parameters. Over the last 10 years, numerous clinical trials have proven the physiological effect of OatWell® oat bran on cholesterol reduction and blood sugar response. Clinical trials have proven the physiological effect of OatWell® oat bran on cholesterol reduction and blood sugar response.

### Innovative uses for OatWell® oat bran in food applications

The World Health Organization (WHO) and Food and Agriculture Organization (FAO) recommend that people in industrialized countries base their diets on low-GI foods in an effort to reduce some of the diseases associated with high-GI diets, such as coronary heart disease, diabetes, and obesity.

### OatWell® oat bran: clinical overview – proven cholesterol lowering effect

![Figure 3](www.innovfoodtech.com)Figure 3

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<td>Blood-glucose level: lower peak-concentration (-36%)</td>
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<td>In a Big carbohydrate portion, each gram of oat bran reduces the GI by 4 units</td>
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<td>Intake of oat bran reduces the GI by 4 units</td>
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<tr>
<td>OatWell® mechanism of action was shown to be the result of delayed and reduced carbohydrate absorption</td>
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### OatWell® oat bran: clinical overview – glycemic response

![Figure 4](www.innovfoodtech.com)Figure 4

#### References

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The effect of Primals® on cholesterol and other blood parameters were also tested in a clinical study by Oresunds Diabetes Team (Lund). The results showed a significant lowering of both total cholesterol (9.4%) and LDL (9.8%) compared with a control product. The primary target group for the yogurt and müsli product is health-conscious consumers.

A new product will soon be launched to the Dutch market: The multi grain bread Vitaalbrood Pró-FIT® has successfully received the Code of Practice of the Voedingscentrum in the Netherlands, in close cooperation with consumer organisations, business organisations, institutes and the government. The producers of food and drinking products can voluntarily use this Code of Practice to scientifically prove the health benefit of the claim of their product. In 2005 the multi grain bread Pró-FIT® containing OatWell® oat bran has successfully received the Code of Practice of the Voedingscentrum.

Approved Health Claims in the Netherlands. Since 1998 there has been an agreement for a Code of Practice in the Netherlands concerning the scientific support for health benefits for food- and drinking products. This Code indicates guidelines that have to be satisfied for the scientific support of a health claim. The Code of Practice has been created by the Voedingscentrum in close cooperation with consumer organisations, business organisations, institutes and the government. The producers of food and drinking products can voluntarily use this Code of Practice to scientifically prove the health benefit of the claim of their product. In 2005 the multi grain bread Pró-FIT® containing OatWell® oat bran has successfully received the Code of Practice of the Voedingscentrum.

Approved Health Claims in the United Kingdom. A scientific dossier was submitted to the UK Joint Health Claims Initiative (JHCI) on behalf of CreaNutrition-Swedish Oat Fiber concerning the use and application of oat β-glucans in oat-based products and their association with reduced risk of cardiovascular disease. The JHCI Expert Committee and the JHCI Council confirmed 2004 that the totality of the evidence substantiated a health claim: whole oats, oat bran, OatWell® oat bran, rolled oats, and whole-oat flour, as part of a diet low in saturated fat and a healthy lifestyle, can reduce cholesterol. The soluble oat fiber β-glucans may serve as a marker for oat products that are the subject of the claim. Products carrying the claim should contain at least 0.75g of soluble oat fiber (β-glucans per serving) which is one-quarter of the suggested daily intake of 3g.

Approved Health Claims in Sweden. Today both generic and product specific claims are allowed. In 2001 regulatory guidelines were established allowing product-specific claims. Product-specific claims must be based on scientific studies and are subject to the scrutiny of the JHCI’s expert committee. In the Swedish market, a product-specific claim, that the product balances or evers out blood glucose levels (GI) after a meal, has been approved for a yogurt containing OatWell® oat bran. A generic claim in two steps about the blood cholesterol-lowering effect of oat β-glucans has also been approved. The following statement is used on the product: "Soluble fibers may, as part of a healthy diet, contribute to healthy cholesterol levels. This product is rich in soluble oat fibers.

Approved Health Claims in the United States. In 1997, the U.S. Food and Drug Administration (FDA) reviewed 37 clinical studies concerning the effect of oat β-glucans on blood cholesterol especially the significance and dose-response of the effect. Based on the findings, the FDA approved the first food-specific claim for oat bran authorising the use of a health claim that states "Soluble fiber from foods such as oat bran, as part of a diet low in saturated fat and cholesterol, may reduce the risk of coronary heart disease." The claim is based on a daily intake of 3g of oat β-glucans, and the food product must contain at least 0.75 g per serving. Nature has created additional health benefits.

Summary

Oat products have a strong image as nutritious, health-promoting ingredients in food applications due to their high bioactive and functional component contents. Probably the most well recognised health-promoting ingredient from oats is β-glucan, a soluble fiber. Significant positive health effects have been attributed to oat β-glucans, including cholesterol control, modulation of glucose and insulin responses, weight management, and improved gastrointestinal function. As a component of oats, β-glucans can be incorporated into a wide variety of innovative food products.

A significant lowering of plasma LDL (up to 10%) cholesterol may be achieved with daily consumption of approximately 3g of β-glucans. A 30-50% reduction in blood glucose peak can be achieved when β-glucans constitute 8-10% of the carbohydrates in a food product.

Approved claims differ from country to country but are permitted in the United States. At the EU level the concept of enhanced function claims (such as may lower cholesterol levels) and disease risk reduction claims (such as reduced risk of CVD) has started to gain wider acceptance and is included in some national guidelines such as those of Belgium, Finland, Netherlands, Sweden and the UK. A proposal for a regulation on nutrition and health claims on foods is under discussion. This regulation is intended to harmonise provisions/action on Member States related to health claims and consumer protection. Furthermore a European commission concerted action – the Process for the Assessment of Scientific Support for Claims on Foods (PASSCLAIM) had the following principal objectives:

- to evaluate existing schemes which assess scientific substantiation;
References


