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Nutritional and functional properties of oats: An update

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Abstract: With snowballing interest in eating for health in the developed world coupled with the endemic obesity problem, much attention is being directed towards delivering soluble fibers to the consumer through food. Cereal foods are obvious and major sources of healthy soluble and insoluble fiber grown over 73% of the total global harvested area. These contribute to over 60% of the world food production providing about 50 percent of protein and energy necessary for the human diet. Oats provide more protein, fiber, iron and zinc than other whole grains. They have high nutritive value both for people and animals because of good taste and an activity of stimulating metabolic changes in the body. Oats are said to be unique among cereals as they are therapeutically active against diabetes, dyslipidemia, hypertension, inflammatory state and vascular injury than other grains which are predominantly insoluble, such as wheat or rice. This review highlights the nutritional value of oats, β-glucan in them as biologically defense modifier, their mode of action against various diseases and enlists various fermented and non-fermented products of oats available in market.

Keywords: Hypertension; β-glucan; Diabetes; Dietary fibers; Cereals; health

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Oats are unique among the cereals; one of the rich sources of dietary fibers among cereals belongs to the Poaceae family like all other grain varieties (Butt et al, 2008). The history of oats can be traced back to about 2000 B.C. As a cultivated crop, oats appear to be substantially later in origin than wheat and barley. The first evidence of oats was found in Egypt and among the lake dwellers of ancient Switzerland (Coffman 1961). Thirteen species and subspecies, all of the family Gramineae, genus *Avena*, are recognized as given in U.S. Department of Agriculture Technical Bulletin 1100. The most commonly cultivated and most popular species in the world today is *Avina sativa* making up more than 75% of the world's cultivars (Coffman 1961).

Oats are able to grow in acidic soil (pH up to 4.5) but perform better on soil having pH 5.3 to 5.7 (Alam and Adams 1979). They are mostly grown in cool moist climates and they are sensitive to hot, dry weather. For these reasons, world oat production is concentrated from the 40th latitude in the southern hemisphere to the 60th latitude in the northern hemisphere. Thus includes mainly Australia, China, North America, Scandinavian, Russia and related countries (Schrickel 1986). European Union is the country that had by far the highest production of oats (8.7 million metric ton) followed by Russia, Canada, U.S.A., Poland and Finland (Agrostats 2009).

Nutritional value of oats

Oats are generally considered "healthy", being touted commercially as nutritious which has led to wider appreciation of oats as human food. Oat grout or whole grains (after removal of hull) contain all three parts of the grain – the germ, endosperm and bran, rich in all valuable nutrients (Fig. 1.). In comparison to other cereals, these are characterized constitute large amount of total protein, carbohydrate (primary starch content), crude fat, dietary fibre (non-starch), unique antioxidants and considerable vitamins and mineral content (Table 1). A good taste and an activity of stimulating metabolic changes in the body make nutritive value of oats high for both people and animals (Brand and Merwe 1996; Lia et al. 1997; Peltonen-Sainio et al. 2004; Peterson 2004). Total carbohydrate content (including cellulose and non-starch polysaccharides)

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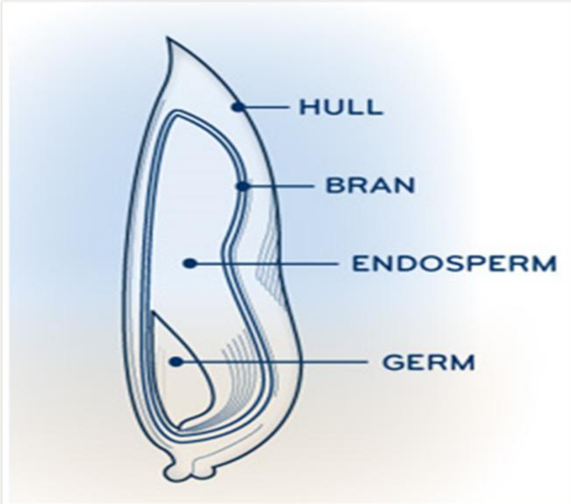


Figure 1 Structure of oat grain (quakeroats.com)

may reach 75-80% of the dry matter. The main component of oat is starch and its content depends on the variety and growing conditions. The amylase content of oat starch ranges from 16-18% to 28.5–28.7% (Mirmoghtadaie et al. 2009).

Table 1 Nutritional composition of whole grain oat and oat bran (Usman *et al*, 2010)

Nutrients	Whole grain oat	Oat bran
Protein	15 - 17 %	15 - 18 %
Starch and sugars	59 - 70 %	10 - 50 %
Fat	~ 4.5 %	~ 6.5 %
Total dietary fibre	~ 12 %	~ 14-15 %
Ash	~ 3.5 %	~ 2.4 %
ß-Glucan	2 - 6 %	5 - 20 %
Cellulose	~ 14 %	~ 2.5%
Lignin	~ 2.4 %	~ 4.5 %

Oats contain a high percentage of oat protein and balanced composition of amino acids (Table 2) which have proved them highly nutritive in comparison to other cereals (Brand and Merwe 1996; Petkov et al. 2001). Highest protein content occurs in oat grout (12.4 to 24.5%) among cereals (Miller et al. 1993; Robbins et al. 1971; Robert et al. 1983). Relatively high protein levels occur in the bran (about 20%) and lower in hull (less than 2%) (Youngs 1982). Oat is the only cereal in which the major portion of the grain protein is soluble in salt and thus classified as globulins and only a small proportion of water soluble albumins and alcohol soluble prolamin. Phenol compounds present in oats and its by-products have a considerable antioxidant potential (Sobotka et al. 2012). Biologically the most important metabolically active proteins of oat are the enzymes. The oat grout, similar to other cereal grains, contains numerous enzymes.

Table 2 Amino acid composition of oats (USDA, 2005)

Amino acids in 1 cup oat (156 gm)	
Tryptophan	0.365 g
Threonine	0.897 g
Isoleucine	1.083 g
Leucine	2.003 g
Lysine	1.094 g
Methionine	0.487 g
Cystine	0.636 g
Phenylalanine	1.396 g
Tyrosine	0.894 g
Valine	1.462 g
Arginine	1.860 g
Histidine	0.632 g
Alanine	1.374 g
Aspartic acid	2.259 g
Glutamic acid	5.791 g
Glycine	1.312 g
Proline	1.457 g
Serine	1.170 g

Early investigations revealed the presence of proteases, maltase, a-amylase, lichenase, phenoxyacetylase and hydroxylase, phosphatase, tyrosinase and lipase as summarized by Caldwell and Pomeranz (1974).A high lipid content of oats makes them different from other cereals and is a good source of essential unsaturated fatty acids (Table 3). The percentage varies from 3.1 to 10.9% but in some high oil varieties it may be as high as 15% (Peterson and Wood, 1997; Schipper and Frey 1991). Triglycerides constitute the main component of lipids and phospholipids, glycolipids, sterols are also present in considerable quantities. The oat starch contains a high lipid content which plays an important role in decreasing the rate and amount of starch retro gradation in oats (Gudmunsson and Eliasson 1989; Paton 1986).

Table 3 Lipid composition of oats (USDA, 2005)

Lipids in 1 cup oat (156 gm)	
Fatty acids, total saturated	1.899 g
12:0	0.037 g
14:0	0.023 g
16:0	1.613 g
18:0	0.101 g
Fatty acids, total monounsaturated	3.398 g
16:1 undifferentiated	0.020 g
18:1 undifferentiated	3.377 g
Fatty acids, total polyunsaturated	3.955 g
18:2 undifferentiated	3.781 g
18:3 undifferentiated	0.173 g
Cholesterol	0 mg

Dietary fibres (non-starch polysaccharides) also known as roughage or bulk are the edible parts of the plants and essential constituents of human nutrition. Although they are not a nutrient, they are nevertheless an important component of our diets. Ingested dietary fibre moves along into the large intestine where it is partially or completely fermented by gut bacteria. During the fermentation process several by-products e.g. short chain fatty acids and gases are formed. It is the combined action of the fermentation process and by-products formed which contribute to the beneficial effects of dietary fibre on health. Oats comprises a very balanced profile of both soluble and insoluble dietary fibers. A high intake of dietary fibre is positively related to several preventive medical and nutritional effects (Spiller 2001) e.g. Dietary fibre complex with its antioxidants and other phytochemicals is most effective against cardiovascular disease and some types of cancer, lowering lipid levels (Jacobs et al. 1998a; Jacobs et al. 1998b; Jacobs et al. 1998; Slavin et al. 2000; Thompson 1994). Mineral content which is 2-3% in oat include phosphorus, potassium, magnesium, and calcium as main components as in other cereal (Table 4).

Table 4 Mineral composition of oats (USDA, 2005)

Mineral content in 1 cup oat (156 gm)	
Calcium, Ca	84 mg
Iron, Fe	7.36 mg
Magnesium, Mg	276 mg
Phosphorus, P	816 mg
Potassium, K	669 mg
Sodium, Na	3 mg
Zinc, Zn	6.19 mg
Copper, Cu	0.977 mg
Manganese, Mn	7.669 mg

Water-soluble vitamin content of oat is summarized in Table V. The folate content of oat is about 20-30 µg/100 gm grain and the biotin concentration 10-15 µg/l00 gm grain.

Table 5 Vitamin composition of oats (USDA, 2005

Vitamins content in 1 cup oat (156 gm)	
Vitamin C, total ascorbic acid	0.0 mg
Thiamin	1.190 mg
Riboflavin	0.217 mg
Niacin	1.499 mg
Pantothenic acid	2.104 mg
Vitamin B-6	0.186 mg
Folate, total	87 µg
Folic acid	0 µg
Folate, food	87 µg
Folate, DFE	87 µg
Vitamin B-12	0.00 µg
Vitamin B-12, added	0.00 µg
Vitamin A, IU	0 IU
Vitamin A, RAE	0 µg
Retinol	0 µg

Other minor components

Oats contain various antioxidants that protect the lipids from oxidation and are important for the storage stability of various oat products. Oats are rich in tocopherols (Morrison et al. 1978; Youngs et al. 1986; Peterson 1995) which have antioxidant activities and contain about 2.3 mg tocopherols /100 gm grain. In addition to this, many low molecular weight phenolic compounds are also present in oat grains. Recent medical and nutritional investigations revealed the important role of natural plant antioxidants in the prevention of some diseases. Recent research has increased our knowledge about the phenol compounds in oats (Collins 1986; Dimberg et al. 2005). Ferulic acid, p-coumaric acid, vanillin, p-hydroxibenzoic acid are some of the compounds detected in oats. Some of these compounds (e.g., ferulic acid) are partly bound to cell wall polysaccharides or proteins. A new group of phenolic acids was obtained from oat grouts and hulls by aqueous alcoholic extraction (Collins et al. 1989). These acids occurred as conjugates linked covalently to the amine function of several different orthoamino-benzoic acids. The structure of one identified compound, designated avenalumic acid, is shown in Fig.2.

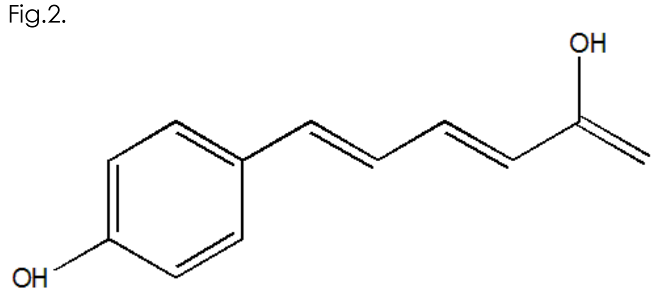
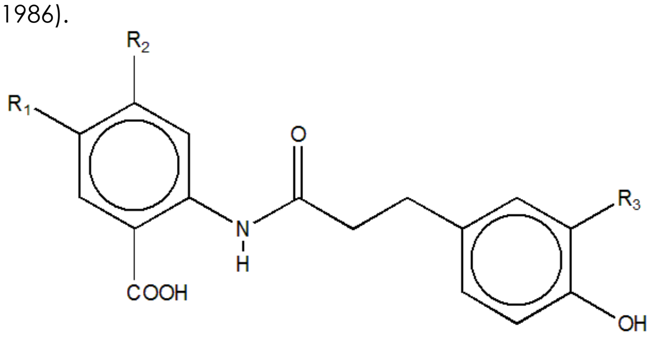


Figure 2 Structure of Avenalumic acid

Another group of phenolic antioxidants present in oats are avenanthramides. These compounds are cinnamoyl-anthranilic acid derivatives.

The structure of two avenanthramides as elucidated by Dimberg et al (1993) is shown in Fig. 3. The antioxidative capacity of aventhramide-2 is about 60% of that of a-tocopherol and seems to be quite heat stable. Caffeic and ferulic acid, known antioxidants, had lower activities. A comparison of 10 oat cultivars revealed that the total amount of two known avenanthramides varied between 40 and 132 µg/g grain.Oat grain also contains small quantities of saponins, designated as avenacoside. These are secondary metabolites which are derived from triterpenoid or steroid cyclisation products of 2, 3-oxidosqualene (Hostettman and Marston 1995). Since many saponins have potent antimicrobial activity the natural role of these molecules in plants is likely to be in conferring protection against attack by potential pathogens (Morrissey and Osbourn 1999) Phytic acid is the main phosphorus reservoir of oats. Lolas et al (1976) found a range of 0.82-1.01% phytic acid in 19 oat cultivars. Miller et al (1980) reported a range of 0.95-1.41% phytic acid in oat grouts from seven cultivars grown for two years in soils with different phosphorus level. Low activity of phytase was found in oats using 31P-NMR spectroscopy because the phytase enzyme gets inactive by the heat treatment normally used during processing of oats for food products (Frolych et al. 1988). That is why; they are officially recognized as safe in contrast to other cereals (Lockhart and Hurt 1986).



COMPUND	R_1	R_2	R_3
AV-A	OH	H	H
AV-B	OH	H	OCH_3
AV-C	OH	H	OH

Figure 3 Structure of Aventhramides

Chemistry of β-glucan from oats (a biological defense modifier)

β-glucan, a type of soluble of dietary fibre and a mixed-linkage polysaccharide of D- glucose units nutritionally potentiates and modulates the immune response. The bonds between D-glucopyranosyl units (Fig. 4) in β-glucans are primarily composed of either β-1,3 (cellotriosyl units) and β-1,4 linkages (cellotetraosyl units) but there are also regions that are more cellulose-like in character, with 4 or more consecutive β-1,4 linked glucose units (Wood et al. 1993). The molar ratio of cellotriose to cellotetraose units (DP3:DP4) is typically 1.5 - 2.3 as far as oat β-glucan is considered (Miller and Fulch 1995).

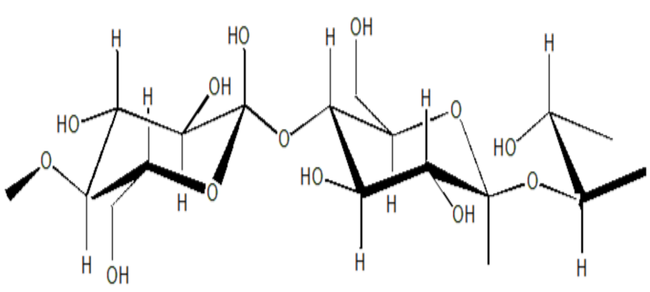


Figure 4 Linkage in Beta-glucan

The β-1, 3 linkages break up the uniform structure of the β-D-glucan molecule and make it soluble and flexible that is why it is a major component of the water extractable fibre fraction (Manthey et al. 1999). The soluble β-glucans make viscous, shear thinning solutions even at low concentrations.

The viscosity is related to the molecular weight and is strongly dependent on the concentration (Åman et al. 2004; Anttila et al. 2004). Lyly et al (2004) observed that with an oat β-glucan preparation of high-molecular weight (average MW = 2,000,000), the maximum practicable concentration of β-glucan in a soup was 0.5 w-% by weight With lower molecular weight preparations (MW ≤ 200,000) of oat, it was possible to add up to 2.0 w-% β-glucan to the soup.

Location of β-glucan in oat grain

β-glucan usually comprises 3.6–5.1 % of dry weight of the oat whole grain (Hampshire 2004). The several factors that affect the concentration of β-glucan include cultivar variation and the growing conditions e.g., nitrogen level, temperature and rainfall (Asp et al. 1992, Brunner and Freed 1994). β-glucans are located throughout the starchy endosperm. They are concentrated in the bran, more precisely in the aleurone and sub-aleurone layer (Fig. 5).

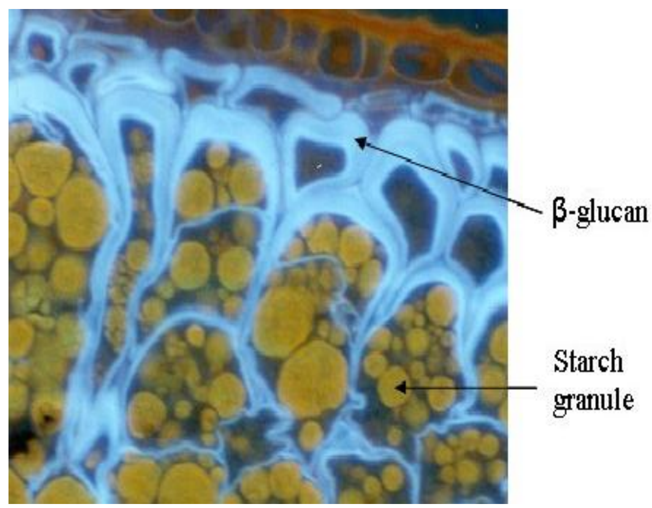


Figure 5 Location of β-glucan in oat grain (oatsandhealth org)

The content of dietary fibre and β-glucan varies between different oat products. Typical concentrations (% of dry weight) are presented below (Table 6).

Therapeutic attributes of oats against diabetes

Table 6 Concentration of dietary fibre and β-glucan in different oat products

	Dietary fibre (%)	Beta-glucan (%)
Oat endosperm flour	5 - 10	1 - 3
Whole grain products	10 - 12	4 - 5
Conventional oat bran products	15 - 20	8 - 12
Oat bran concentrates	20 – 35	15 – 22
Beta-glucan isolates	80 - 100	Up to 80

and its associated metabolic disorders

Oat against type 2 diabetes

Insulin resistance, the main component and causative factor of metabolic syndrome associated with type 2 diabetes is an essential target in the therapeutic approach of oat β- glucans. The dietary intake of total as well as soluble and insoluble fiber is inversely associated with insulin resistance, supporting evidence that a high intake of dietary fiber is associated with enhanced insulin sensitivity (Galisteo 2008; Ylonen et al. 2003). Oat β- glucans have been used in several clinical trials to reduce glucose level in blood.

Oats act against diabetes and cause the lowering of blood glucose level through many ways (Fig. 6). Oat β-glucans favor increased glucose uptake into skeletal muscle and improves insulin sensitivity by delaying stomach emptying because of high viscosity and stability with pH (Butt et al. 2008) so that dietary glucose is absorbed more gradually (Kiho et al. 1995). The comparative reduction of glucagon response after the oat extracts may be partially responsible for the reduction in glucose concentrations (Judith et al. 1995). Another possible mechanism for oat β-glucans to reduce blood glucose level is mediated by signal pathway through PI3K/Akt activation.

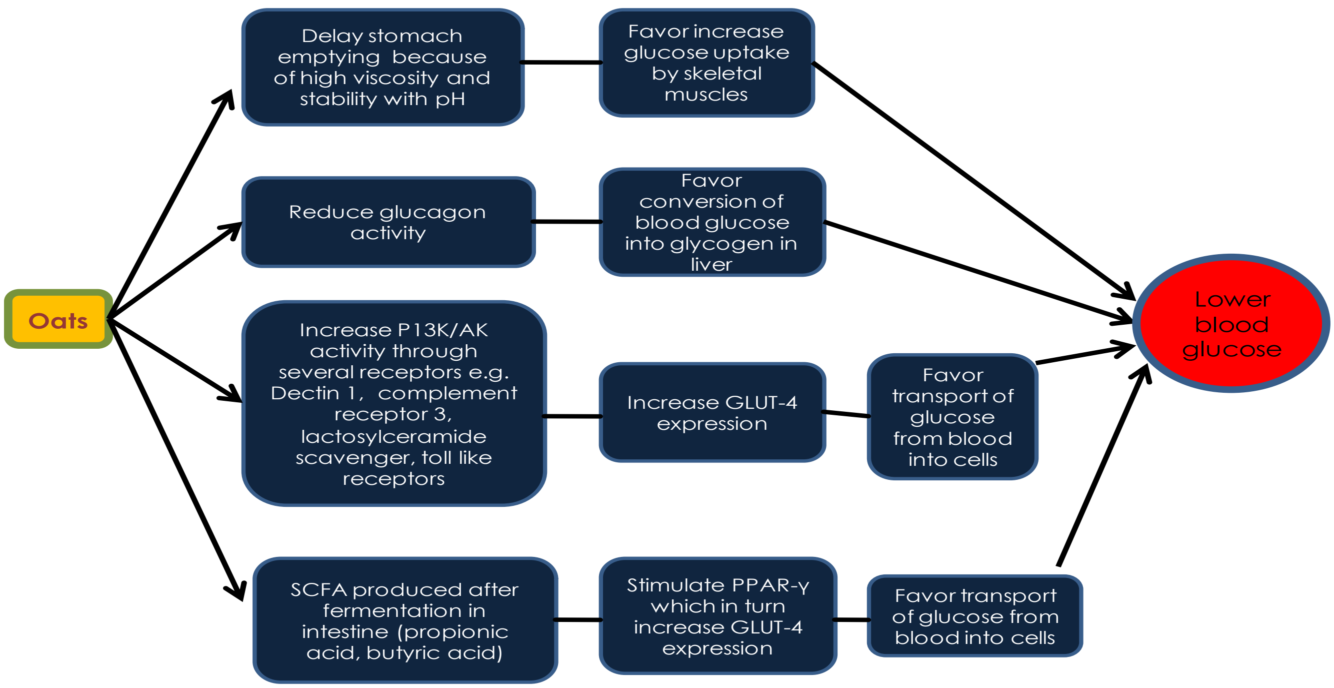


Figure 6 Mechanism of action of oats against diabetes

Studies showed that oat β-glucan (~5gm per day) decrease the glycemic response upto 50% after ingestion of 35 gm carbohydrate (Tappy et al. 1996) and in a 50 g carbohydrate portion each gram of - glucan reduces the GI by 4 units (Jenkins et al. 2002). It has been also shown that oat bran flour was more effective than oat bran crisp explained by the three times higher β-glucan content in oat bran flour (Saris 2003; Tapola et al. 2005) against type 2 diabetes. After ingestion of the oat (bran flour or crisp), the blood glucose levels were lower at 15, 30, and 45 min but higher at 90 min after 12.5 g glucose loading (Tapola et al. 2005). These changes reduce the feeling of hunger caused by rapid decrease in blood glucose (Ludwig 2003; Saris 2003). Thus, β-glucans decrease appetite and reduce food intake. Zerm et al recently also reported that oatmeal diet days may improve insulin resistance in patients with type 2 diabetes mellitus (Zerm et al. 2013).

Mechanism of action against type 2 diabetes

Decreased PI3K/Akt activity has been shown to play a key role in the pathogenesis of type 2 diabetes. β-glucans have been demonstrated to increase PI3K/Akt through several receptors (Hsu et al. 2002; Chen and Seviour 2007). These receptors stimulated by β-glucans include Dectin-1, complement receptor 3 lactosylceramide, scavenger and toll like receptors; each induces specific signal pathways. The interaction between β-glucans and their receptors has been studied by Brown (2006) and Chen and Seviour (2007). The administration of β-glucans could restore decreased PI3K in diabetes as mushroom extract have been shown to activate PI3K pathway (Li et al. 2006; Lee et al. 2008). These β-glucans can bind to dectin-1 receptor to stimulate the signal pathway (Underhill et al. 2005; Trinidad et al. 2006; Brown 2006; Olsson and Sundler 2007). Another β-glucan lentinan binds to scavenger receptors which can also activate PI3K pathway (Rice et al. 2002; Mineo et al. 2003).

A study in stroke-prone spontaneously hypertensive rats suggests that dietary fibre (mainly soluble) supplementation effectively prevents insulin resistance by increasing skeletal muscle plasma membrane content of the insulin-responsive glucose transporter type (GLUT-4) by a mechanism different from the activation of the phosphatidylinositol-3 4 series of fatty acids stimulate peroxisome proliferator activated receptor PPARγ, whose activation has been reported to increase GLUT-4 content in adipocytes (Park et al. 1998). Therefore, it has been suggested and proved that short chain fatty acids (SCFAs) such as propionic and butyric acids, which result from anaerobic fermentation by bacteria of soluble fermentable dietary fibre in the colon (Cummings et al. 1987), increase muscle GLUT-4 via PPARγ (Songs et al. 2000).

also reported that oat bran high fibre diet significantly reduces plasma cholesterol level in hypercholesterolemic rats. Recently it was reported that instant oatmeal consumed daily for 6 weeks significantly increased fiber intake and decreased major risk factors for CVD in Chinese adults with hypercholesterolemia (Jhang et al. 2012). Rabey stated that oat bran appeared more efficient than barley bran in lowering the lipid profile levels in hypercholesterolemic rats (Rabey et al. 2013).

Mechanism of action against dyslipidemia

The mechanism of oat bran soluble fibres to lower LDL (Fig. 7) is considered to be mediated by bile acids binding property of β-glucans. Therefore β-glucans increase exclusion of bile acids (Marlett 1997;

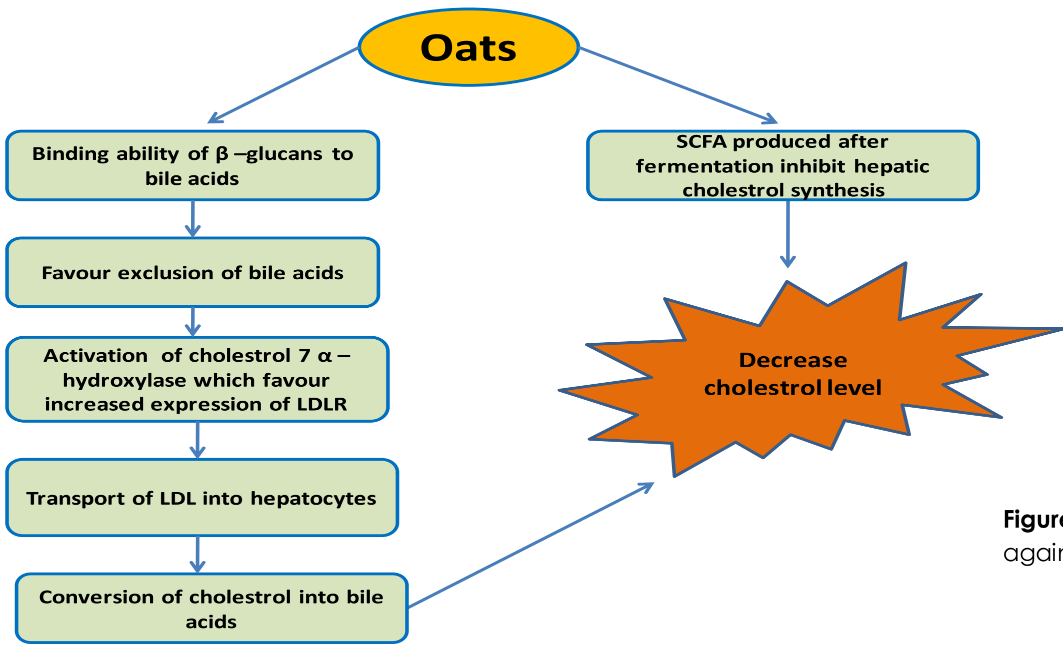


Figure 7 Action of Oat against dyslipidemia

Oat against dyslipidemia

β-glucans have been shown to decrease LDL cholesterol and increase HDL to alleviate possibly dyslipidemia and reduce CVD (Anderson 1995; Reyna-Villasmil et al. 2007; Kapur et al. 2008). The required dose of β-glucan is 0.75 g/serving in food. Oats were first found to have a cholesterol-lowering effect and the active component was identified as β-glucans (Kerckhoffs et al. 2002). On the basis of numerous (Butt et al. 2008) clinical studies, the US Food and Drug Administration (FDA) permitted the use of a claim that oat soluble fibre has the ability to reduce the risk of heart disease. Oats reduced both serum total cholesterol and LDL cholesterol compared with control (Davidson et al. 1991; Van Horn et al. 1991; Gerhardt and Gallo 1998; Kerckhoffs et al. 2003; Karmally et al. 2005; Naumann et al. 2006; Reyna-Villasmil et al. 2007; Theuwissen and Mensink 2007). In 20 hypercholesterolemic male patients, oat bran was shown to be better than wheat bran in lowing cholesterol (Anderson et al. 1991). Usman et al (2010)

Ellegard and Anderson 2007) and this in turn activates cholesterol 7a-hydroxylase and up-regulates low-density lipoprotein receptor (LDLR) and thus increase the transport of LDL into hepatocytes and the conversion of cholesterol into bile acids (Nilsson et al. 2007). It has been reported that every 1% reduction in LDL is associated with a decreased risk for CHD of 1% to 3% (Reynolds, 2000). In addition, oat β-glucans have also been shown to be fermented by human fecal micro biota to produce short-chain fatty acids such as acetate, propionate and butyrate and after absorption into the portal vein both acetate and propionate inhibit hepatic cholesterol synthesis (Wright et al. 1990). This in turn produces the hypocholesteolemic effect (Han et al. 2004; Drzikova et al. 2005; Alminger and Eklund-Jonsson 2008; Hughes et al. 2008). The mechanism of oat bran soluble fibres to lower LDL is considered to be mediated by bile acids binding property of β-glucans. Therefore β- glucans increase exclusion of bile acids (Marlett 1997; Ellegard and

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Oat against hypertension

A clinical trial with food containing oat β-glucans showed reduced blood pressure in the subjects with body mass index above medians (31.5 kg/m2) (Maki et al. 2007). This is further demonstrated by another trial that also showed effective role of oat against hypertension (He et al. 2004). However, no pure β-glucan has been used for these studies and thus it is difficult to identify which components are effective (Chen and Raymond 2008). In a randomized, double-blind, placebo-controlled trial in 110 participants aged 30 to 65 years who had untreated but higher than optimal blood pressure or Stage 1 hypertension (He et al. 2004), the effects of supplemented soluble fibre intake from oat bran on blood pressure for 12 weeks were analyzed. It was found that both systolic and diastolic blood pressure was significantly reduced in the study participants who consumed a high-fibre diet (mean reduction by 3.4 and 2.2 mmHg, respectively).

Mechanism of action against hypertension

Increased body weight is a strong risk factor for hypertension (Neter et al. 2003). Several mechanisms for a potential effect of dietary fibre intake on blood pressure have been hypothesized. Dietary fibre has numerous effects on the digestion and absorption of

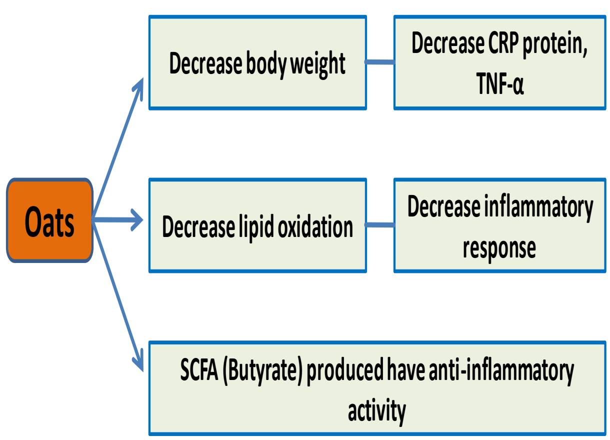

Figure 8 Oat actions against Proinflammation

foods. Insulin resistance and its concomitant compensatory hyperinsulinemia have been suggested as major underlying pathogenesis mechanisms for the development of hypertension (Ferrannini et al. 1987). In this way, effectiveness of both soluble and insoluble fibres in reducing insulin resistance and insulin levels in both diabetic and healthy persons (McKeown et al. 2002, King et al. 2005, Qi et al. 2005) would contribute to treating or preventing hypertension. Intake of dietary fibre has also been shown to efficiently reduce body weight (Rigaud et al. 1990) and weight gain (Liu et al. 2003).

Oat against proinflammatory state

There are interesting reports about the effects of dietary fibre intake on the acute-phase response marker CRP and the inflammatory cytokines IL-6, IL-18 and TNF-a whose levels are found abnormally elevated in the type 2 diabetes. Some studies have suggested an association between consumption of dietary fibre and the anti-inflammatory adiponectin. A study in diabetic women (Qi et al. 2006) indicated that after adjustment for age, body mass index (BMI), lifestyle and dietary covariates, intake of cereal fibres was associated with significantly decreasing trends of CRP (C reactive protein) and TNF-a receptor 2 among women with type 2 diabetes.

Mechanism of action against proinflammatory state

Oat intake effect favoring weight loss could be involved as most weight loss studies have shown that decreasing body weight was related to decreases in CRP (Dietrich et al. 2005), TNF-a (Dandona et al. 1998) and to increases in adiponectin circulating levels of obese women (Esposito et al. 2003). In a study, King (2005) suggested that dietary fibre decreases lipid oxidation, which in turn is associated with decreased inflammation. These anti-inflammatory effects of dietary fibre could also be attributed, in the case of fermentable fibres, to the production of butyrate (Fig. 8). Clinical trials suggest that butyrate has anti-inflammatory properties in pathologies such as inflammatory bowel disease (Patz et al. 1996), and it has been described for anti- inflammatory activity in different human cellular types such as macrophages and monocytes (Segain et al. 2000).

Oat against vascular injury

Vascular injury may contribute to the pathogenesis of CVD (Liuba and Pesonen 2005; Kibos et al. 2007) associated with type 2 diabetes. Dietary fibres may increase collagen synthesis (Wei et al. 2002). The study has shown that β-glucan can help in healing of wound in db/db mice (Berdal et al. 2007).

Oat based product

Oats usage in human foods has increased as information on oats beneficial nutritional properties has come to light. The authorization of the heart health claim for oats in the United States by the FDA is especially significant. Additionally, recent investigations on the health implications of minor oat constituents such as avenathramides have raised hopes that the nutritional benefits of oats in human diets may go well beyond those currently recognized. There are many non-fermented and fermented oat based products are available in the market (Table 7).

Before oats are used to produce oat products, the hulls are removed, leaving the oat grout. Traditional commercial non-fermented oat products include rolled oats (whole-grain flakes), steel-cut grouts, quick oat flakes, baby oat flakes, instant oats, oat bran, and oat flour.

Table 7 Fermented oats based products

Fermented oat products	Manufacturer	
Oatly	CeBa Food AB, Lund	Enzymatic hydrolysis of oat kernals, milk-free product
Oatwell	CreaNutrition AG, Switzerland Swedish oat fibre AB, Sweden	Oat bran
Primaliv™	Skåne mejerier, Malmö, Sweden	Yoghurt containing oat fibres
Oatrim	ConAgra, Quaker Oats, Rôhne-Poulenc	Enzymatic hydrolysis of oat flour
YOSA®	Bioferme, Finland	fermented with a combination of probiotic bacteria i.e. *Bifidobacterium lactis* BB-12™ and *Lactobacillus acidophilus* LA-5™
Velle	Velle Oats, St. Petersburg, Russia	Oat Fermentation with Lactic acid bacteria
Oat based fermented product	Martensson *et al,* 2001	Fermented with commercial yoghurt starter cultures
Oat Bio Lacto	Bekers *et al*, 2001	Fermented with probiotic lactic acid bacteria i.e. *Lactobacillus acidophilus* T_{20} and *Bifidobacteria* and commercial starter culture ABT-1
Oat based probiotic drink	Angelov *et al,* 2006	Fermented with Lactic acid bacteria *Lactobacillus plantarum*

Conclusion

Due to increased cost and side-effects of medication, consumer's interest is snowballing towards dietary modifications for improvement of health. It is a well documented fact that oats are effective against common disorders of lifestyle *in vogue*. Oats which earlier were grown as forage and fodder are a unique combinations of proteins, fats, dietary fibres, minerals, vitamins and alkaloid polyphenols (aventhramides). They act as good substrate for the growth of pro-biotic lactic acid bacteria which enhance their potential to improve the health and well being of consumers. Though lactic acid fermentation of oats is an ancient processing method yet most of the oat based products available in market are non- fermented and even fermented ones are invariably non dairy based. Nevertheless, limited information is available regarding the development of functional food product having oats and pro-biotic in a completely milk-based product mainly due to lack of acceptability with an appearance, texture and sensory quality mainly the beany flavor associated with these products. The sensory attributes play pivotal role in consumer acceptance of novel functional foods. Once the healthful effects of such foods are validated and established through systematically designed studies using small animal models and human trials, their acceptability can be increased by flavoring these products using fruits, various artificial sugars and by modifying their texture using various stabilizers.

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