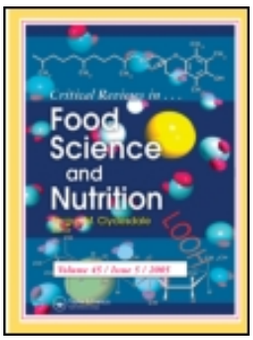

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Avena sativa (Oat), A Potential Neutraceutical and Therapeutic Agent: An Overview

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The aim of the present review article is to summarize the available information related to the availability, production, chemical composition, pharmacological activity, and traditional uses of Avena sativa to highlight its potential to contribute to human health. Oats are now cultivated worldwide and form an important dietary staple for the people in number of countries. Several varieties of oats are available. It is a rich source of protein, contains a number of important minerals, lipids, β-glucan, a mixed-linkage polysaccharide, which forms an important part of oat dietary fiber, and also contains various other phytoconstituents like avenanthramides, an indole alkaloid-gramine, flavonoids, flavonolignans, triterpenoid saponins, sterols, and tocols. Traditionally oats have been in use since long and are considered as stimulant, antispasmodic, antitumor, diuretic, and neurotonic. Oat possesses different pharmacological activities like antioxidant, anti-inflammatory, wound healing, immunomodulatory, antidiabetic, anticholesterolaemic, etc. A wide spectrum of biological activities indicates that oat is a potential therapeutic agent.

Keywords Avenanthramides, anticholesterolaemic, antidiabetic, antioxidant, immunomodulatory, dietary fiber, β-glucan, oat, groat

INTRODUCTION

Avena sativa L. (Gramineae), commonly known as Oat, Groats, Haber, Hafer, Avena, Straw, Oatmeal, is a species of cereal grain grown for its seed (Coffman, 1977; Gibbs Russell et al., 1990; Suttie, 2004). Oat originated in England, France, Poland, Germany, and Russia and is now cultivated worldwide. The word Avena is derived from the Sanskrit word "avi," meaning "sheep" or "avasa," meaning "foodstuff." The wild ancestor of *A. sativa* is *A. sterilis* which grows in the Fertile Crescent of the Near East. Domesticated oats came relatively late in Europe, far from the Near East. The Indian species is equated with *A. byzantina* C. Koch. Oats is usually considered a secondary crop derived from a weed of wheat and barley and leading to its eventual domestication (Zhou et al., 1999). Oat bread was first manufactured in England. In Scotland they are held in high esteem to this day, as a mainstay of the national diet and they serve as an important dietary staple for the people of many countries before being substituted by coffee and bread. Samuel Johnson in his dictionary mentioned oats as a grain, which is generally given to horses in England, but supports the people in Scotland (Gibson and Benson, 2002; Ensminger et al., 1983; Zhou et al., 1999). The wild red oat is considered the ancestor of modern oat, a plant originating in Asia. Oats have been cultivated for two thousand years in various regions throughout the world. Use of oat has been advocated for medicinal purposes as well as a food.

A. sativa L. is an annual grass about 1.5 meters high; culms tufted or solitary, erect or bent at the base, smooth. The leaves are non-articulate, green, and the sheaths rounded on the back; the ligules are blunt and membranous. The inflorescence is a diffuse panicle with 2–3 florets, all bisexual or the distal one or two may be reduced and male or sterile; glumes sub-equal 7–11 veined; longer glumes 17–30 mm; lemmas 7–9 veined, either bifid or with a bristle at their apex; lowest lemma is 12–25 mm. The rachilla of the cultivated oat does not disarticulate at maturity (that of several weed species do). Its lemmas are rarely awed. The grain is tightly enclosed by the hard lemma and palea. Seed size varies with the cultivar; it is commonly about 30,000 seeds per kilogram crop (Gibbs Russell et al., 1990). Other varieties of oats are Red oat (*A. Byzantine*), Large Naked Oat (*A. nuda*), a Hull-less oat where the kernel is loose within the hull, Small Naked oat (*A. nudibrevis*), a smaller oat, Wild Red oat (*A. steriles*) from which cultivated red oats are developed, Desert oat (*A. wiestii*), Slender oat (*A. barbata*), Sand oat

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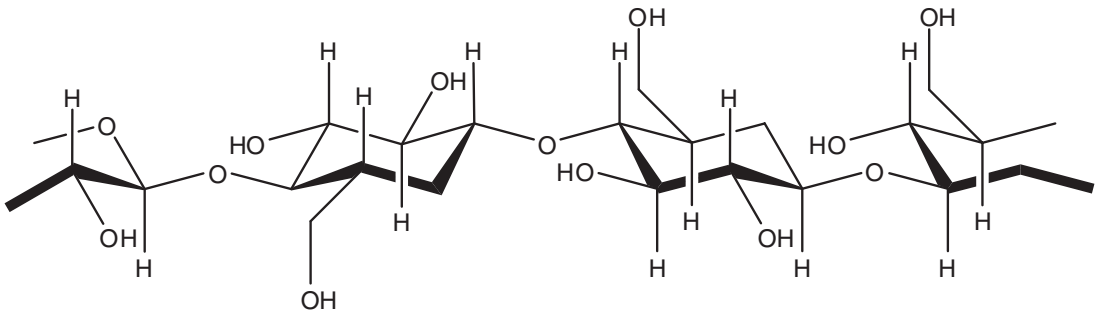


Figure 1 Structure of β-glucan with $\beta 1 \longrightarrow 4$ and $\beta 1 \longrightarrow 3$ linkages.

(*A. strigosa*), Abyssinian oat (*A. abyssinica*, *A. wiestii*), Wild oat (*A. fatua*) which resembles the common oat, *A. sativa*, but is more vigorous and not grown for grain. Oats have been cultivated for two thousand years in various regions throughout the world. Oats are grown throughout the temperate zones. They have a lower summer heat requirement and greater tolerance of rain than other cereals like wheat, rye, or barley. They are particularly important in areas with cool, wet summers. Oats are an annual plant, and can be planted either in autumn (harvested in late summer) or in the spring (harvested in early autumn). Red oat (*A. byzantine*) is cultivated both in winter and spring. The variation in the chemical constituents in different varieties of oat has been reported (Dimberg et al., 1996).

Depending on the degree of processing, oats are classified into various types. Whole oats have a hard outer hull that must be removed for human consumption. Hulled oats are known as "groats." The oat hull is a source of the chemical furfural. In oat groats the hard unpalatable outer hull is removed from the whole oat grain, keeping the kernel's outer bran layer intact. Steel-cut oats, also known as pinhead oats and sometimes referred to as coarse or rough oatmeal, are made by passing groats through steel cutters which chop each one into three or four pieces. They are very nutritious as they contain the whole grain including the oat bran. Rolled oats are prepared by steaming groats and flattening them with a roller. Instant oats are made in a similar way like rolled quick-cooking oats, except they are steamed longer period and rolled more thinly. Oat flour is obtained by grounding the oats and usually available in three grades: coarse, medium, and fine (Winfield et al., 2007).

PRODUCTION

Oat is produced in various countries around the world. According to the UN Food and Agriculture organization (FAOSTAT, 2009) the total world production of oats in the year 2008 was around 25.8 million metric tons (mmt); Russia being the top producer (5.8 mmt) followed by Canada (4.2 mmt), United States (1.3 mmt), Poland (1.2 mmt), Finland (1.2 mmt), Australia (1.2 mmt), Ukraine (0.9 mmt), Germany, Belarus, and China, (0.8, 0.6, and 0.4 mmt, respectively).

Phytoconstituents

A wide range of chemical constituents like carbohydrates, proteins, avenanthramides, tocols, lipids, alkaloids, flavonoids, saponins, and sterols have been reported from *A. sativa*.

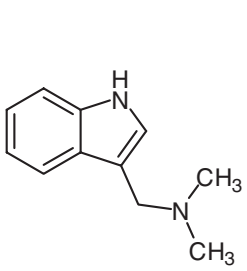
Carbohydrates

The presence of mucilage (β-glucan), 3–4% sugar (glucose, fructose) from fruits and β-glucan, pentosans, saccharose, kestose, neokestose, bifurcose, neobifurcose, acid galactoarabinoxylan from green herb of *A. sativa* have been reported (Hansel et al., 1992). Oat β-glucan is a mixed-linkage polysaccharide of D-glucose units, and an important part of oat dietary fiber. The bonds between D-glucopyranosyl units in β-glucan are either β1–3 or β1–4 linkages (Fig. 1). The 1–3-linkages break up the uniform structure of the β-D-glucan molecule and make it soluble and flexible. β-Glucan is primarily composed of β-1–3 linked cellotriosyl and cellotetraosyl units, but there are also cellulose-like β-1–4 linked glucose units (Wood, 1993).

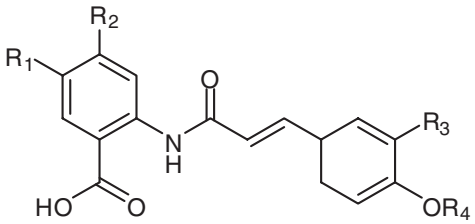
Starch is the most abundant component of the oat grain. It contains about 25–30% amylase and has typical gelatinization characteristics. It develops unusually high viscosity on cooling; cooled oat starches are clearer, less firm, more elastic, more adhesive, and less susceptible to retrogradation than other cereal starches (Webster, 2002).

Proteins

Oat is very rich in protein content and is the only cereal containing a globulin or legume-like protein, avenalin, as the major (80%) storage protein. The unreduced heterogenous proteins exist as disulphide linked α and β-isomers of molecular weight 53000–58000 (Brinegar and Peterson, 1982). Globulins are water soluble compounds. Other type of cereal proteins are gluten and zein (prolamines or prolamins). The minor protein of oat is avenin, a prolamine. Oat protein is nearly equivalent in quality to soy protein, which according to WHO is equal to that of meat, milk, and egg protein. The protein content of the hull-less oat kernel (groat) ranges from 12–24%, the highest among cereals (Lasztity, 1984; 1999).



1. Gramine



Aventhramides	R_1	R_2	R_3	R_4
2. AV-A	OH	H	H	H
3. 2AV-B	OH	H	OCH_3	H
4. AV-C	OH	H	OH	H
5. Tranilast	H	H	OCH_3	CH_3

Figure 2 Alkaloids from *Avena sativa*.

Lipid

Various lipids like steryl esters, triglycerides, partial glycerides, free fatty acids, glycolipids, and phospholipids were separated from oat (Hutchinson and Martin, 1955). Fifty molecular species of N-acylphosphatidylethanolamine and twenty-four molecular species of acylphosphatidylglycerol were identified in oats by HPLC (Holmback et al., 2001). The phospholipid content was similar in all cultivars. Triglycerides contained less palmitic and more oleic acid than the glycolipids or phospholipids. The presence of 9 glycolipids and 11 phospholipids has been reported (Welch, 1975). A galactolipid 1-[(9′Z), (12′Z)-octadecadienoyl]-2-[(15′′R)-{9′′′Z), (12′′′Z)-octadecadienoyloxy}-(9′′Z), (12′′Z)-octadecadienoyl]-3-(α-D-galactopyranosyl-1,6-β-D-galactopyranosyl)-glycerol was also reported from oat seeds (Hamberg et al., 1998).

Alkaloids

Indole Alkaloid. An indole alkaloid, gramine (Fig. 2), has been isolated from *A. sativa* (Duke, 1992); fruit is thought to be responsible for weak sedative effect.

Avenanthramides. Avenanthramides are phenolic compounds and consist of anthranilic and hydroanthranilic acid linked to one of several hydroxycinnamic acids through an amide bond. The three most predominant avenanthramides (Fig. 2) in oat are formed from hydroxyanthranilic acid and *p*-coumaric, ferulic, or caffeic acids (Chen et al., 2007; Collins, 1986; 1989; Collins et al., 1991; Collins and Mullin, 1988; Dimberg et al., 1993; 2005; Peterson et al., 2001; Peterson, 2004). The amount of avenanthramides in grains ranges between 2 mg/kg-53 mg/kg (Pihlava et al., 2004).

A phytochemical examination of the methanolic extracts of oat groats and hulls revealed the presence of more than 25 distinct avenanthramides in groat extracts and about 20 in hull extracts, of which 15 were common to both groat and hull preparations (Collins, 1989).

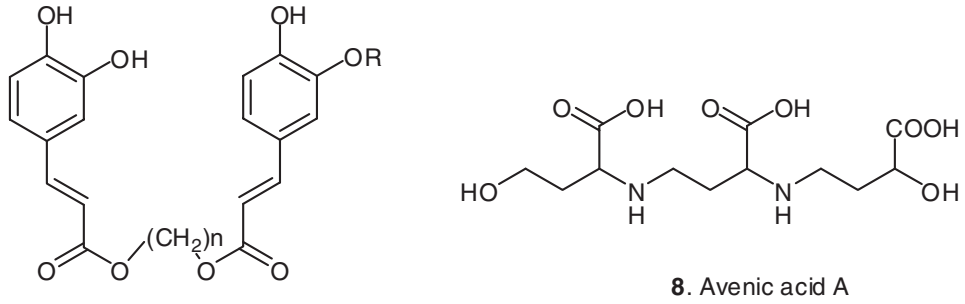
Tocols. Tocols (tocopherols and tocotrienols), vitamin E, are the natural antioxidants present in grains and exist as lipid-soluble compounds (Peterson, 2004). α-Tocotrienol is the major tocol present in oats, followed by α-tocopherol while other tocotrienols are present in minor amounts (Peterson et al., 2007).

The biological activity of tocols results from their ability to donate phenolic hydrogen atoms to free radicals, thus breaking destructive chain reactions (Kamal-Eldin and Appelqvist, 1996). Tocols also have the ability to reduce serum cholesterol concentration and to inhibit the growth of certain cancer cells (Peterson and Qureshi, 1993). The tocotrienols, the major tocols present in oat, are stronger free radical scavengers than tocopherols (Pihlava et al., 2004).

Organic Acids. A number of organic acids like maleic, citric, malonic, aconitic, oxalic acid, and an antioxidant hydrolyzed into caffeic, ferulic acids (Fig. 3) and aliphatic alcohol were reported from fruits while avenic acid A and B (Fig. 3) were reported from green herb of *A. sativa.* Avenalumic acids were also reported from oat groats and hulls (Collins et al., 1991; Daniels and Martin, 1968; Durkee and Thivierge, 1977). The presence of a sucrose diester of a substituted β-truxinic acid has also been reported (Dimberg et al., 2001).

Flavonoids. More than twenty-eight flavonoids including 4,5-dihydroxy-7-methoxy-8-C-glucosyl-O-rhamnoside, 7-methoxy-vitexin-O-rhamnoside, apigenin-6,8-di-C-glucoside, apigenin-6-C-glucoside, apigenin-6-C-glucosyl-arabinoside, apigenin-8-C-arabinosylhexoside, apigenin-8-C-rhamnosylglucoside, avenalumin-I, isoorientin, isoorientin-2′′-O-arabinoside, isoorientin-2′′-O-β-D-diglycoside, isoorientin-7-O- β-D-glycoside, isoswertisin-2′′-O- α-L-rhamnoside, isoswertisin-2′′-rhamnoside, isocoparine, isovitexin-2′′-O-arabinoside, luteolin-6-C-glucoside, luteolin-6-C-glucosyl-arabinoside, tricin-4′-O- β-D-glycoside, tricin-7-O- β-D-glycoside, vitexin-2′′-rhamnoside, tricin, and putrescine have been identified in the seeds and the green parts of the plant (Chopin et al., 1977; Duke, 1992).

Rhamnosylisoswertisin may have phytoalexin properties, protecting the plant against mycoses and O-methyl-apigenin-



6. Caffeic acid derivatives (R=H)
7. Ferulic acid derivatives (R=CH_3)

8. Avenic acid A

Figure 3 Organic acids reported from *Avena sativa*.

C-deoxyhexoside-O-hexoside, obtained from oat, provides protection against major cereal nematodes, Hetrodera and Pratylenchus (Soriano et al., 2004). Three flavonolignans (Fig. 4) have been isolated from the oat herb; among them two were diastereomericflavonolignans- tricin 4-O-(threo-α-guaiacylglyceryl)ether and tricin-4-O-(erythro-α-guaiacylglyceryl)ether known as salcolins A (9) and B (10), respectively (Wenzig et al., 2005; Duke, 1992).

Saponins. Triterpenoid saponins are unusual amongst the monocots. Triterpenoid saponins, avenacin from the root, and avenacosides A and B from the leaves of *A. sativa* have been reported (Tschesche et al., 1969; Tschesche and Lauven, 1971; Osbourn, 2003). Genes for avenacin biosynthesis may have potential for the development of disease resistance cultivated varieties (Kitchen et al., 2003). Avenacoside A and B (Fig. 5) have also been reported from the leaves of *A. sativa* (Crombie et al., 1986).

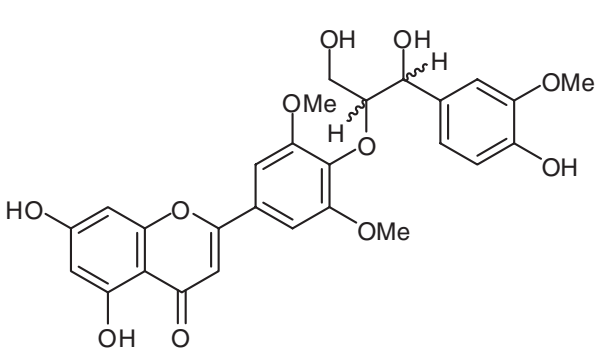
Sterols. Sterols, sterylglycosides (SG), acylated sterylglycosides (ASG), and steroidal saponins are present in oat leaves. The sterol parts consisted mainly of sitosterol, stigmasterol, cholesterol, cholestenol, Δ^5-avenasterol, Δ^7-avenasterol, campesterol, campestenol, lophenol, stigmastenol, Δ^7-stigmastenol, and Δ^7-cholestenol (Eichenberger and Urban, 1984; Wakabayashi et al., 1986). Quantitative variation in different sterol groups has been reported. A higher percentage of sitosterol at the expense of stigmasterol was typical for SG and ASG as compared to free sterols (Wakabayashi et al., 1986).

Uses. Oat has been globally recognized as a nutraceutical, a vitalizer, and a pharmaceutical in general. It has been included in the British Herbal Pharmacopoeia (Anon: British Herbal Pharmacopoeia, 1983). Besides their medicinal importance they are also used in making beer, for treatment during withdrawal from tobacco (Anand, 1974), and opium addiction. Oats are also used as livestock feed for horses, cattle, and in some breeds of dogs and chicken.

The parts having medicinal properties are the fresh or dried above-ground plant, the ripe, dried fruits, and the dried, threshed leaf, and stem. The use of oat straw has also been mentioned in some texts but there is little medicinal action in this part of the plant (Weiss, 1988).

Traditional Uses

In folk medicine, oats are used to treat nervous exhaustion, insomnia, and weakness of the nerves. They are considered as antispasmodic, antitumor, cyanogenetic, demulcent, diuretic, neurotonic, stimulant, tonic, and vulnerary. A tea made from oats was considered to be useful in rheumatic conditions and



9. Threo
10. Erythro

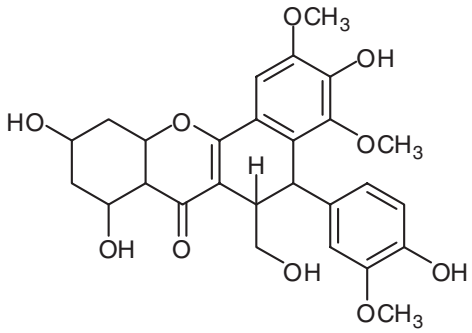


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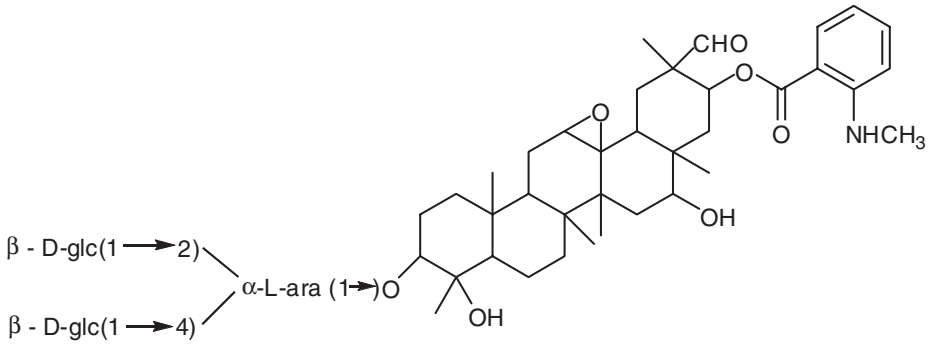
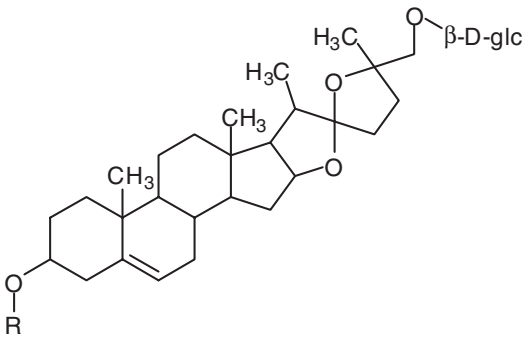
Figure 4 Flavonoids reported from *Avena sativa*.



12. Avenacin



13. Avenacoside A : R= β-D-glc - [(4 - 1) rha] - [(2 - 1) β D -glc]

14. Avenacoside B : R= β-D-glc - [(4 - 1) rha] - [(2 - 1) β D -glc -(3 -1) β -D -glc]

Figure 5 Triterpenoid saponins reported from *Avena sativa*.

to treat water retention. A tincture of the green tops of oats has been used as a nerve stimulant and also to help in withdrawal from tobacco and opium addiction. Oats were often used in baths to treat insomnia and anxiety as well as in a variety of skin conditions, including burns and eczema. Its use in the bath water helps to keep the skin soft due to its emollient action. The seeds are folk remedies for tumors while straws are said to be useful in rheumatism (Duke and Wain, 1981). The straw has also a wide range of uses such as for bio-mass, fiber, mulch, paper-making, building board, thatching, and also as a stuffing material for mattresses. Oat hulls are used for the production of furfural which is a chemical intermediate used for the manufacture of nylon, lubricating oils, butadiene, phenolic resin glues, and rubber tread compositions. Oats hull supply about 22% of the required furfural raw materials. They are also used in the manufacture of construction boards, cellulose pulp, and as a filter in breweries. An extract of oat straw prevents feeding by the striped cucumber beetle (Carruthers, 1986; Chevallier, 1996; Chiej, 1984; Duke, 1983; Hill, 1952; Komarov, 1968; Welch, 1995).

FOOD AND HEALTH

Oats have numerous uses in food. It is eaten as porridge, used in a variety of baked products like oatcakes, oatmeal cookies, and oat bread; it is also used as an ingredient in many cold cereals, in particular muesli and granola. Oat ice cream and oat milk are also available. Due to its natural preservative and antioxidant qualities oat is used in bread, milk, milk powder, butter, ice cream, fish oil, olive oil, bacon, lard, frozen fish, and frozen sausage. Oat flour is added to bread for flavor; it can also be used as a coffee substitute and for preparation of beer, such as oatmeal stout (Gauldie, 1981). Oat lipids (fats) has potential as excellent emulsifiers for use in bread and chocolate while oat gum has been suggested as an alternative to gelatin as a thickening and stabilizing agent in ice cream, sauces and salad dressings (Sikora et al., 2008).

Modern Nutraceuticals and Pharmaceuticals

Oats are generally considered "healthy" and the consumption of oat bran is believed to lower LDL ("bad") cholesterol, and possibly to reduce the risk of heart disease. These properties have led to wider appreciation of oats as human food (Bidlack, 1998; Truswell, 2002; Brown et al., 1999; Kelly et al., 2007).

Fibers

Both soluble and insoluble fibers are present in oat. It has been reported that diet with high fiber content prevents many

Table 1 Fiber content in some plant foods

Food	Fiber (g/100 g)
Oat	10.3
Wheat	9.5
Barley	9.2
Corn	7.3
Rice	2.8
Fruit & vegetable	0.5-5.0
Nuts	4.0-12.0
Pulses	5.0-18.0

diseases (Anderson et al., 2009). The fiber content of some important foods has been presented in Table 1 (Saturni et al., 2010). It has a high content of soluble fiber in the form of β-glucan, and also contains insoluble fiber-arabinoxylans and cellulose.

Soluble Fiber

Oats contain more soluble fiber than any other grain, resulting in slower digestion and a feeling of fullness. β-D-glucans is a class of nondigestible polysaccharide found in nature in sources such as grains, barley, yeast, bacteria, algae, and mushrooms. But oat β-glucan is a soluble fiber. The fibers are not digested in the small intestine, but the soluble β-glucan is believed to increase the viscosity of the food bolus, leading to a delay in gastric emptying, enhanced gut fill, and slower absorption of nutrients. So, bulkier stool is produced and the bulk is sped faster along the gut; this reduces the exposure time of the sensitive gut lining tissues to various irritants and carcinogens present in the waste. The physiological effects are in part mediated via insulin and gastrointestinal hormone secretion (Malkki and Virtanen, 2001).

β-glucans has proven to help in lowering cholesterol. 3 g of soluble fiber daily from oat foods having a diet with low saturated fat and cholesterol may reduce the risk of heart disease. The FDA has allowed a health claim to be made on the labels of foods containing soluble fiber from whole oats but the whole oat-containing food must provide at least 0.75 grams of soluble fiber per serving. The β-glucan content present in various oat products are given in Table 2 (Manthey et al., 1999).

Cereal grains and β-glucans whole grains are traditionally used in nutrition as carriers of fibers in addition to other molecules like vitamins, microelements, etc. The content of β-glucan in wheat is around 1% whereas it is about 3–7% in oats. The potential use of β-glucan as a food ingredient in functional dietary fiber is gaining importance. The health claims of oat have been attributed to the presence of β-glucans (Brennan and Cleary, 2005). Rolled oats, oat bran, and other oat products have sufficient β-glucans to be beneficial to health. Several studies have documented the beneficial role of oat in controlling blood pressure, arterial health, and insulin level. Even if cereal products were not considered as prebiotics, they have been recommended recently as healthy food for their strong hypocholesterolemic properties. The fat replacer OatrimTM combines the activity of typical dietary fibers with prebiotic activity (Tomasik and Tomasik, 2003). Studies carried out to evaluate the role of oat β-glucan suggest that it may reduce cholesterol in hypercholesterolemic patients, thereby reducing the risk of heart disease (Bidlack, 1998). β-glucans have been shown to reduce serum cholesterol levels (both total and LDL-cholesterol) and the physiological responses appear to be affected by solution concentration and the molar mass of glucan. The mechanism is still not clear. It has been suggested that the role of viscosity alteration in digesta is important because it increases intestinal viscosity, which may decrease the absorption of cholesterol and the reabsorption of bile acids. Inclusion of oat β-glucan into breakfast cereals, even at low levels (below 5%), could reduce the postprandial glycemic response (dose dependent) by up to 50%. Increased amounts did not show large reductions. When β-glucans (2.5–5%) added bread is used in food systems, significant reductions in starch degradation and sugar release, proportional to the amount of β-glucans incorporated into the bread, were observed. This will have a beneficial effect on obesity and diabetes. So, the blood glucose levels of diabetic and prediabetic individuals can be moderated by using food rich in β-glucans. According to the FDA, the use of dietary fiber containing oat β-glucan reduces the glycemic and cholesterol responses of individuals. 20–30 g/day of total dietary fiber is the recommended intake by the National Cancer Institute (Butrum et al., 1988). OatrimTM, an oat β-glucan concentrate, has been reported to reduce glycemic responses in both men and women, but it is less effective than the NutrimTM from the barley β-glucans in the regulation of glucose and insulin responses (Brennan and Cleary, 2005). β-glucans have also been shown to stimulate immune responses by the alteration they cause in the colonic microflora or the alteration in SCFA production by the microflora (Brownlee et al., 2005; Warrand, 2006).

Lipids

Oat is very rich in lipid content. It contains more than 10% lipid as compared to about 2–3% in wheat and most other cereals (in maize about 17%). The polar lipid content of oats which is about 33% (8–17% glycolipid and 10–20% phospholipid) is more than that of other cereals (Sahasrabudhe, 1979). Lecithin is the major (45–51%) phospholipid (Youngs et al., 1977).

Table 2 Dietary fiber and β-glucan content in different oat products

Fiber (%)	Oat endosperm flour	Whole grain products	Conventional oat bran products	Oat bran concentrate	β-glucan isolate
Dietary fiber	5–10	10–12	15–20	20–35	80–100
β-glucan	1–3	4–5	8–12	15–22	Upto 80

Table 3 Nutritional value of Oat[a]

Nutrient	Units	Per 1 cup/156 g	Nutrient	Units	Per 1 cup /156 g
Proximates			Vitamin D (D2 + D3)	mcg	0.0
Water	g	12.82	Vitamin D	IU	0
Energy	kcal	607	**Lipids**		
Energy	kJ	2540	Fatty acids, total saturated	g	1.899
Protein	g	26.35	12:0	g	0.037
Total lipid (fat)	g	10.76	14:0	g	0.023
Ash	g	2.68	16:0	g	1.613
Carbohydrate, by difference	g	103.38	18:0	g	0.101
Fiber, total dietary	g	16.5	Fatty acids, total monounsaturated	g	3.398
Minerals			16:1 undifferentiated	g	0.020
Calcium, Ca	mg	84	18:1 undifferentiated	g	3.377
Iron, Fe	mg	7.36	Fatty acids, total polyunsaturated	g	3.955
Magnesium, Mg	mg	276	18:2 undifferentiated	g	3.781
Phosphorus, P	mg	816	18:3 undifferentiated	g	0.173
Potassium, K	mg	669	Cholesterol	mg	0
Sodium, Na	mg	3	**Amino acids**		
Zinc, Zn	mg	6.19	Tryptophan	g	0.365
Copper, Cu	mg	0.977	Threonine	g	0.897
Manganese, Mn	mg	7.669	Isoleucine	g	1.083
Vitamins			Leucine	g	2.003
Vitamin C, total ascorbic acid	mg	0.0	Lysine	g	1.094
Thiamin	mg	1.190	Methionine	g	0.487
Riboflavin	mg	0.217	Cystine	g	0.636
Niacin	mg	1.499	Phenylalanine	g	1.396
Pantothenic acid	mg	2.104	Tyrosine	g	0.894
Vitamin B-6	mg	0.186	Valine	g	1.462
Folate, total	mcg	87	Arginine	g	1.860
Folic acid	mcg	0	Histidine	g	0.632
Folate, food	mcg	87	Alanine	g	1.374
Folate, DFE	mcg DFE	87	Aspartic acid	g	2.259
Vitamin B-12	mcg	0.00	Glutamic acid	g	5.791
Vitamin B-12, added	mcg	0.00	Glycine	g	1.312
Vitamin A, RAE	mcg, RAE	0	Proline	g	1.457
Retinol	mcg	0	Serine	g	1.170
Vitamin A, IU	IU	0			

[a]USDA National Nutrient Database for Standard Reference, Release 22 (2009).

Proteins

Oat is the only cereal containing a globulin or legume-like protein, avenalin as a major (80%) storage protein. Globulins are characterized by water solubility and so they may be turned into milk but not into bread. The more typical cereal proteins such as gluten and zein are prolamines (prolamins). A minor prolamine protein of oat is avenin.

The quality of oat protein is nearly equivalent to soy protein which, according to WHO is equal to meat, milk, and egg protein. The protein content of the hull-less oat kernel (groat) ranges from 12–24%, highest among cereals (Lasztity, 1999). The nutritional value of oat has been presented in Table 3 (Anon: USDA, 2009).

Vitamins

Both water and fat soluble vitamins are present in oat. The vitamins content in seeds are - Vitamin A: 0.862 mg/100 g (mucilage), β-carotene: <1.0 μg/100 g (rolled oat), Vitamin B1/thiamine: 3.89–7.07 mg/kg, Vitamin B6: 56 nmol/g, Vitamin E/ tocopherol: 4, 3 (α -tocopherol) -0.5 -1.0 (Barnes and Taylor, 1979; Bognar, 1986; Gregory and Sartain, 1991; Heinoven et al., 1989; Jahn-Deesbach, 1979).

Mineral Substances

Oats are also rich in mineral content. The mineral content of oat seeds and green oats are given in Table 4 (Anon: EMEA, 2008).

Table 4 Minerals content of the fruits and green parts of *A. sativa* (mg/100 g)

Elements	Oats seeds	Green oats
K	355	1140
Ca	79.6	660
Mg	129	715
P	342	330
Mn	3.7	8.5
Fe	5.8	39
Zn	4.5	19.2
Cu	0.47	2.1

Oats are also a very good source of selenium, a necessary cofactor of the important antioxidant, glutathione peroxidase.

PHARMACOLOGY

Oats and it constituents are reported to possess varied pharmacological activities like lowering of blood cholesterol and blood sugar, immunomodulatory, anticancer, antioxidant, antiatherogenic, topical anti-inflammatory, useful in controlling childhood asthma, body weight, etc.

Cholesterol Lowering Effect

Several studies have shown that oat products have a cholesterol lowering effect in normal and hypercholesterolemic subjects. In a majority of studies there was significant reduction in total cholesterol, with a similar percentage of reduction in LDL-cholesterol (Truswell, 2002; Brown et al., 1999). A dose dependent response in the cholesterol lowering properties of oats with an average dose of oat soluble fiber of 3.2 g/d (range 1.1–7.6 g/d) has been reported (Davidson et al., 1991). There was a statistically significant reduction in total and LDL-cholesterol by mixed linked (1→3), 1→4)-β-D-glucan, the main soluble fiber component in oats.

The mechanisms of the cholesterol lowering effects of oat soluble fiber is not certain but it is suggested that the viscous properties of β-glucan play a key role by slowing absorption of nutrients and increasing bile acid excretion (Lia et al., 1995; Zhang et al., 1993). Modification of rheology of the gut lumen probably is responsible for these effects. This indicates that the physiological response is mechanically or physically based rather than biochemically.

In another study (Liu et al., 2004) when human arterial wall cells were exposed to purified avenenthramides, isolated from oats, for 24 hours, it significantly suppressed the production of several types of molecules involved in the attachment of monocytes (immune cells in the bloodstream) to the arterial wall; the first step in the development of atherosclerosis. Oat avenanthramides suppressed production of ICAM-1 (intracellular adhesion molecule-1) and VCAM-1 (vascular adhesion molecule-1), E-selectin, and the secretion of pro-inflammatory cytokines IL-6, chemokines IL-8, and protein MCP-1 (monocyte chemo attractant protein) (Liu et al., 2004).

Antioxidant Activity

A number of studies have been carried out to evaluate the antioxidant activity of oat and it exhibited good antioxidant activity (Bratt et al. 2003; Daniels and Martin, 1967; Daniels et al., 1963; Emmons et al., 1999; Handelman et al., 1999; Xing and White, 1997; Xu et al., 2009). It has been suggested that most of the antioxidant capacity of oat is likely derived from polar phenolic compounds (Handelman et al., 1999).

Selenium is a necessary cofactor of the important antioxidant, glutathione peroxidase (Pleban et al., 1982). Selenium works with vitamin E in numerous vital antioxidant systems throughout the body (Emmons et al., 1999). Due to the antioxidant actions selenium becomes helpful in decreasing asthma symptoms and in the prevention of heart disease. Organic acids such as glyceryl esters of caffeic and ferulic acids also act as antioxidants (Daniels and Martin, 1968). Aventhramides are another group of phenolic compounds responsible for the antioxidant activity of oats (Bratt et al., 2003; Chen et al., 2007; Dimberg et al., 1993; Emmons and Peterson, 2001; Peterson et al., 2001; 2002). The results of an experimental study in which laboratory animals were fed saline containing 0.25 g of phenol-rich oat bran indicated that aventhramides, the antioxidant compound present in oat, is bioavailable (peak blood concentration of aventhramides reached after 40 minutes) and it helps in preventing free radicals from damaging LDL cholesterol, thus reducing the risk of cardiovascular disease (Bazzano et al., 2003; Chen et al., 2004). The antioxidant ability of avenanthramides to protect LDL cholesterol against oxidation (free radical damage) induced by copper was also tested. Not only did the avenanthramides increase the amount of time before LDL became oxidized, but when vitamin C was added, the oat phenols interacted synergistically with the vitamin, extending the time during which LDL was protected from 137 to 216 minutes.

The antioxidant activity of avenanthramides was more than the typical cereal components ferulic acid, gentisic acid, p-hydroxybenzoic acid, protocatechuic acid, syringic acid, vanillic acid, vanillin, and phytic acid. Oat samples showed a very good antioxidant activity when the antioxidant capacity during 28 days of storage was measured by the linoleic acid assay (Martinez-Tome et al., 2004).

In a comparative study for antioxidant effect of *A. sativa* and *Amaranthus hypochondriacus* rats were fed with a basal diet or with basal diet with 1% cholesterol. Each experimental group consisted of 12 rats. The cholesterol fed rats received additionally 10% oats meal or 10% *A. hypochondriacus*. In both oat and amaranth groups, cholesterol, LDL-cholesterol, and triglycerides levels were lower and the HDL-cholesterol level was higher as compared to the cholesterol-only group. Highly significant difference ($P < 0.001$) was observed in Oat group than the Amaranth ($P < 0.05$) group (Czerwinski et al., 2004). The cholesterol lowering potency of β-glucan (2, 4, or 8 g/100 g) has been reported to be comparable to that of barley in Syrian golden F_1B hamsters fed with a cholesterol rich diet for 9 weeks (Delaney et al., 2003).

In-vitro Inhibitory Activity on MAO-B

MAO-B inhibitors are used in Parkinson's disease. *A. sativa* herb extracts, made with different ethanol concentrations, were tested in an in vitro model by using a commercially available

enzyme preparation of monoamine oxidase –B (MAO-B). The extracts prepared with higher concentrations of ethanol are reported to exhibit more prominent inhibitions of 44.3 ± 1.4%, 57.2 ± 0.8%, and 78.6 ± 0.4% with ethanol concentrations 15%, 30%, and 50%, respectively (Zhou and Panchuk-Voloshina, 1997).

Inhibitory Activity on PDE-4 Activity

A. sativa herb extracts, made with different ethanol concentrations, were also tested on phosphodiesterase- 4 (PDE-4) with an undifferentiated U937 human monocytic cell line, which enabled to test the hormonal regulation of the c-AMP. The c-AMP content could be temporarily increased by adding the beta-agonists and salbutamol followed by an increase in PDE. PDE decreases the content of c-AMP by converting c-AMP to AMP. Inhibition of PDE will result in increased intracellular c-AMP levels. Residual c-AMP was quantitatively assessed by measuring the radioactivity corresponding with [^{3}H] cAMP after separation by ion exchange column chromatography (Torphy et al., 1992). Extracts prepared with higher concentrations of ethanol showed higher inhibitions of the PDE-4 activity (inhibition of 35.3 ± 3.3%, 66.5 ± 1.2%, and 89.5 ± 2.4% with ethanol concentrations 15%, 30%, and 50%, respectively). Inhibition of PDE-4 will result in higher intracellular c-AMP levels and can influence in vitro results.

Effect on Nitric Oxide Production and Vascular Smooth Muscle

Avenanthramide-2c is reported to enhance nitric oxide production and to inhibit vascular smooth muscle cell proliferation. There was a concentration dependent (between 40 and 120 μM) inhibition of the incorporation of ^{3}H thymidine in human vascular smooth muscle cells which was reversible after washing out avenanthramide-2c. The effect may possibly be due to an inhibition of proliferation of the vascular smooth muscle. Same concentrations of the compound stimulated the synthesis of NO in a human endothelial cell line ($P < 0.05$) (Nie et al., 2006).

Anti-Atherogenic Activity

The potential antiatherogenic activity of partially purified avenanthramides from oat was tested by evaluating their effects on adhesion of monocytes to human aortic endothelial cell monolayer, expression of adhesion molecules, and production of proinflammatory cytokines and chemokines by the endothelial cells. The pre-incubation of HAEC with 4, 20, and 40 ng/mL avenanthramide enriched mixture (AEM) for 24 hours significantly decreased adhesion of U937 monocytic cells to interleukin-1beta-stimulated HAEC. The inhibition was concentration dependent. Pre-incubation of HAEC with AEM at 20 and 40 μg/mL, but not at 4 μg/mL, for 24 hours significantly suppressed IL-1beta- stimulated expressions of intracellular adhesion molecule-1, vascular cell adhesion molecule-1 and E-selectine and the secretion of proinflammatory cytokines IL-6, chemokines IL-8, and monocyte chemo attractant E-selectine and the protein (MCP)-1 (Liu et al., 2004).

Topical Anti-Inflammatory Activity

Topical anti-inflammatory activity of oatmeal extract was studied by using vasoactive intestinal peptide (VIP) as trigger to cause inflammation in human skin cell culture. Vasodilatation was significantly increased after application of VIP. The mean surface of the dilated vessels and edema were significantly decreased after treatment with oatmeal extract. The extract treatment also decreased TNF-alpha (Boisnic et al., 2003). The effect of a spray containing Rhealba oat extract on human skin fibroblasts was also studied (Boisnic et. al., 2005). A punch biopsy as a source of epidermal cells was implanted on this dermal equivalent, where a multilayered epidermis developed. Epidermal growth was evaluated by immuno-histochemical analysis of mitotic activity (5-bromo-2′-deoxyuridine [BrDu] incorporation). The extension of the neoepithelium in comparison with untreated reconstituted skin over 22 days was evaluated histologically. On the 12th day 16% of positive BrDu basal cells were detected after spray treatment in comparison with 4.2% positive cells in untreated reconstituted skin ($p < 0.05$). During epidermal differentiation between days 12 and 22, a significant increase in the number of cellular epithelial layers after 16 and 18 days of spray treatment was seen. The extension of re-epithelialization was also significantly increased after spray treatment on days 16 and 18.

A colloidal extract of *A. sativa* (Avena Rhealba®) has been reported to produce an inhibition of the Ca-ionophore A23187 on the liberation of arachidonic acid from phospholipids and the subsequent metabolism into prostaglandins and leukotrienes (Aries et al., 2003; 2005). The inhibition of the biosynthesis of prostacyclin (measured as 6-ketoPGF$_{1\alpha}$) was dose dependent. Also the expression of phospholipase and COX-2 was tempered. The results of the study indicate the potential of oat as a topical anti-inflammatory substance.

Cytokines, which are produced by cutaneous cells during inflammatory processes, represent a large series of regulatory proteins of the immunologic system. Interleukins (IL2, IL4, IL5, and IL13) are produced in atopic conditions (e.g., contact eczema and psoriasis). A colloidal extract of Avena is reported to stimulate the production of the anti-inflammatory TGFβ1 by keratinocytes and inhibit the production of interleukins. During cutaneous inflammation processes the neuro-immunocutaneous system is destabilized. Production of substance P, a neurologic mediator, is increased and consequently nitric oxide (NO) is seen. An Avena flour preparation has been reported to block the substance P mediated stimulation of NO synthesis and inhibition of the expression of NO-synthase has been identified as basic

mechanism (Aries et al., 1999). Boyer et al. (1998) studied the anti-inflammatory activity of oatmeal extract by using a lauryl sulphate irritation model. Oat straw from the aerial part is used in inflammation of skin warts (Capasso et al., 2003).

Wound Healing Property

The activity of *A. sativa* flour preparations was evaluated on experimental wound healing models: by the expression of the vascular endothelial growth factor (VEGF) to human keratinocytes cell line, migratory response of human keratinocytes cell line using the modified Boyden chambers and contraction of collagen lattices by human fibroblasts. The sample significantly induced VEGF production by keratinocytes, increased keratinocytes migration and induced a denser arrangement of collagen fibrils by fibroblasts. The findings of the study suggested the ability of oat to induce the cellular responses involved in wound healing (Aries et al., 1999).

Effect on Behavioral Activity

The effect of Neuravena®, wild green oat extract, on behavioral changes in animal was studied and it showed beneficial effects on mental performance like learning ability and alertness (Anon: Frutarom, 2008).

Antimicrobial Activity

The oral or parenteral oat β -glucan treatment enhanced the resistance to *S. aureus* and *E. vermiformis* infection in mice. β-glucan increased the number of splenic Interferon gamma (IFN-γ)- secreting cells and induced a change in the lymphocyte population (Thy1.2+, CD4+, CD8) in the mesenteric lymph nodes (Yun et al., 2003). Avenacin, isolated from the oat root, is reported to be a potent inhibitor for the growth of number of microorganisms including *Ophiobolus graminis, Ceratostomella ulmi, Mycobacterium tuberculosis, Neurospora crassa, Saccharomyces pastorianus, Candida albicans* (Maizel et al., 1964).

Immunomodulatory Effect

Dhillon and Bhatia (2008) evaluated the effect of oat seed and leaf extracts on immune status of swiss albino mice by employing Nitro Blue Tetrazolium reduction (NBT), Inducible Nitric Oxide Synthase (INOS), Phagocytosis (bactericidal activity), and ELISA in vivo tests. The results revealed that both the aqueous oat seed extract and leaf extract were immunopotentiating, the former being more bioactive.

Prevention of Cancer

Consumption of whole-grain foods is associated with a decreased risk of cancer. Selenium, present in oat, is involved in DNA repair and is associated with reduced risk for cancer, especially colon cancer. In the large bowel, soluble dietary fiber increases the fermentation activity, especially production of butyric acid, enhances growth and colonization of some probiotic bacterial strains, increases production of microbial mass and thus helps in the removal of nitrogen via feces. It also increases wet weight of stools, thereby alleviating constipation. Short-chain fatty acids formed enhance cell proliferation of the colonic mucosa and this reduces the risk of colon cancer (Jacobs et al., 1998; Malkki and Virtanen, 2001; Anderson et al., 2009).

CLINICAL TRIALS

Antidiabetic Activity

Foods yielding low postprandial glycemic responses have been suggested to be beneficial for the dietary prevention of type 2 diabetes (Livesey et al., 2008). Oat β-glucan can attenuate the glycemic response (Jenkins et al., 2002). The increase of intestinal viscosity due to high molecular weight β-glucan is crucial for obtaining the positive effect of β-glucan on the peak blood glucose (Wood, 2007). It has been reported that the inclusion of oat β-glucan into breakfast cereals could reduce the postprandial glycemic response up to 50%. At low levels (below 5%) the response was dose dependent whereas at the levels above 5% it did not show significant reductions in the glycemic response (Tappy et al., 1996). These findings will be of importance for deciding the appropriate levels of β-glucan inclusion in food systems.

Studies to evaluate the effect of inclusion of β-glucan enriched cereal in foods was carried out in Type 2 diabetic patients and their glycemic indices (GI) were found to be significantly lower than the GI of the group with white bread. The results of the study suggest that the blood glucose levels of diabetic and pre-diabetic individuals can be moderated by using β-glucan rich foods and so oat has great potential (Jenkins et al., 2002; Wolever et al., 1991).

Oats and other whole grains are a rich source of magnesium which acts as a co-factor for more than 300 enzymes, including enzymes involved in the body's use of glucose and insulin secretion (Wacker and Parisi, 1968).

Foods containing at least 51% whole grains by weight (and are also low in fat, saturated fat, and cholesterol) are permitted by FDA to display a health claim stating that its consumption is linked to lower risk of heart disease and certain cancers. The data of an 8-year trial, involving 41,186 participants of the Black Women's Health Study, revealed inverse associations between magnesium, calcium, and major food sources in relation to type 2 diabetes.

Risk of type 2 diabetes was 31% lower in the group of black women frequently eating whole grains as compared to those eating the lesser quantity of those magnesium-rich foods. When the women's dietary intake of magnesium intake was considered by itself, a beneficial, but lesser-19%-reduction in risk of type 2 diabetes was found, indicating that whole grains offer special benefits in promoting healthy blood sugar control (Van Dam et al., 2006). Daily consumption of low-fat dairy foods was also helpful in lowering the risk of type 2 diabetes by 13%.

Immunomodulatory Effect

Some polysaccharides of algae, fungi, and plant cells walls are reported to have immunomodulating effects. Mixed-linked β-1, 3:1, 6-glucans from fungi (e.g., mushrooms) and yeast have been known as potent immunostimulants against infectious diseases and cancer (Hong et al., 2004). These β-glucans stimulate macrophage, neutrophil, and NK cells via β-glucan-specific receptor sites on their cell surface membranes (CR3 and dectin-1). When bound, β-glucan activates these cells and provides immune defenses that protect the organism from microbial, viral, parasitic, and fungal infections, and result in antitumor and anticancer activity (Hong et al., 2004; Davis et al., 2004). Immune responses of leukocytes and enterocytes (intestinal cells) were enhanced after consumption of oat β-glucan but it is not clear whether this stimulatory effect contributes to enhanced protection of invading harmful pathogens (Ramakers et al., 2007).

Cardiovascular Diseases

Eating of high fiber foods, such as oats, helps in preventing the heart disease (Djousse and Gaziano, 2007). The results of a 19.6 years study involving 21,376 American adults revealed (after adjusting the confounding factors like age, smoking, alcohol consumption, vegetable consumption, use of vitamins, exercise, and history of heart disease) that the group taking a daily morning bowl of whole grain cereal had a 29% lower risk of heart failure. People eating high fiber, 21 g/day, had fewer incidences of both coronary heart disease (CHD) and cardiovascular disease (CVD) (12% and 11% less respectively) as compared to those eating the less fiber, 5 g/day. Persons eating the most water-soluble dietary fiber showed better response with 15% and 10% reduced risk of CHD and CVD, respectively.

The result of another 3-year prospective study involving over 200 postmenopausal women with CVD revealed that those eating at least 6 servings of whole grains each week experienced slowed progression of atherosclerosis, the build-up of plaque that narrows the vessels through which blood flows, and less progression in stenosis, the narrowing of the diameter of arterial passageways. The intake of fiber from fruits, vegetables, and refined grains was not associated with a lessening in CVD progression (Erkkila et al., 2005).

The results of a randomized double-blinded placebo-controlled clinical trial for the prevention of restenosis revealed that tranilast, an oat aventhramide, block the proliferation and deposition of vascular matrix fibroids and the migration of aortic smooth muscle cells into the vessel intima following arterial injury. The tranilast restenosis following angioplasty trial showed that oral administration of 600 mg/day of tranilast for 3 months markedly reduced the restenosis rate after percutaneous transluminal coronary angioplasty (PTCA) for de novo lesions (Holmes et al., 2002; Tamai et al., 2002).

Effect on Celiac Disease

Celiac disease is an immune-mediated disorder of the small bowel that is triggered by exposure to gluten and its symptoms include chronic diarrhea, weight loss, and abdominal distention. The only effective treatment is life-long gluten free diet.

Reported clinical data indicates that oats can be included in a gluten-free diet (Faulkner-Hogg et al., 1999). A number of studies have suggested that the ingestion of oats is safe (Dor and Shanahan, 2002; Hardman et al., 1997; Janatuinen et al., 1995; 2002; Lundin et al., 2003; Vader et al., 2002). By inclusion of oats into diet it would be possible to diversify the diet of celiac patients by providing cereal character and high fiber content foods. It has also been reported that patients with celiac disease can tolerate uncontaminated oats (Holm et al., 2006; Storsrud et al., 2003). Numbers of commercially available oats are contaminated with wheat, barley, or other prolamin containing cereals.

In a double blind, multi-center study involving 8 clinics treating 116 children newly diagnosed celiac disease for a year the children were randomly assigned to receive either the standard gluten-free diet (no wheat, barley, rye, or oats) or a gluten-free diet with some wheat-free oat products. The result of the study showed that in both groups, the mucosal lining of the small bowel (which is damaged by wheat gluten in celiac disease) had healed and the immune system (which is excessively reactive in celiac patients) had returned to normal (Hogberg et al., 2004).

Protection against Pre- and Post-Menopausal Breast Cancer

Diet rich in fiber obtained from whole grains, such as oats, and fruits offer significant protection against breast cancer for pre-menopausal women (Cade et al., 2007). It has been reported that pre-menopausal women eating >30 g fiber daily had a 52% lower risk of breast cancer than those eating <20 g fiber/day while there was 41% reduced risk in those taking 13 g fiber/day as compared to the women consuming daily 4 g or less fiber. Fiber from fruit also exhibited protective action. Pre-menopausal women whose diets supplied the most fiber from fruit (at least 6 g /day) had a 29% reduced risk of breast cancer, compared to those with the lowest fruit fiber intake (2 g or less per day).

Results of a prospective study involving 51,823 postmenopausal women for an average of 8.3 years showed a 34% reduction in breast cancer risk for those consuming the most fruit fiber compared to those consuming the least. In addition, in the subgroup of women who had ever used hormone replacement, those consuming the more fiber, especially cereal fiber, had a 50% reduction in their risk of breast cancer compared to those consuming less (Suzuki et al., 2008). A cup of oatmeal supplies 15% of the RDI for fiber. So, a cup of oatmeal in the morning will help in meeting daily RDI for fiber.

Effect on Asthma

The findings of a study on allergy and asthma in childhood revealed that increasing consumption of whole grains and fish could reduce the risk of childhood asthma by about 50% (Tabak et al., 2006). Though a possible link between antioxidant intake, particularly vitamins C and E, and asthma have been suggested, no association between asthma and intake of fruits, vegetables, and dairy products was reported. The children's intake of both whole grains and fish was significantly linked to incidence of wheezing and current asthma. In children with a low intake of fish and whole grains, the prevalence of wheezing was about 20% while it was only 4.2% in children with a high intake of both foods. Low intake of fish and whole grains has also been correlated with a much higher incidence of current asthma (16.7%) as compared to only 2.8% incidence of current asthma among children with a high intake of both foods. High intakes of whole grains and fish were found to be associated with a 54% and 66% reduction in the probability of being asthmatic, respectively.

The increased sensitivity to factors that cause narrowing of the airways is called bronchial hyper responsiveness (BHR). The probability of having asthma with bronchial hyper responsiveness (BHR) was reported to be reduced by 72 and 88% when children had a high-intake of whole grains and fish, respectively (Tabak et al., 2006).

Obesity

Oat derived β-glucan is reported to reduce the body weight and BMI (Body mass index) significantly. A constant intake of oatmeal lowered the risk of obesity. On digestion the soluble fiber of oats forms a gel, which increases the viscosity of the contents of the stomach and small intestine. The gel delays stomach emptying making one feel full for a longer period, which helps in weight loss (Artiss et al., 2006; Reyna-Villasmil et al., 2007; Sanchez et al., 2008).

Effect on Uric Acid Excretion

Studies have been conducted to find out the effect of oat products on uric acid excretion. In one study patients (51 patients divided into 2 groups of average age 30 and 58) with elevated uric acid levels were treated by giving a herbal tea containing 75% *A. sativa* (Remaining 25% includes *Alchemilla alpine* 5% and *Urtica dioica* and *Hypericum perforatum* 10% each) for 4 weeks. At the end of the treatment period lower serum uric acid levels were observed, as compared to the initial levels (Krug, 1985).

The same tea formula was compared in an open cross-over study with mineral water. Patients with asymptomatic hyperuricemia (6.5 to10 mg%) were included and the duration of treatment was 20 days. Patients were given 6 cups of tea or 6 glasses of water in addition to the normal fluid intake. There was a one week wash-out period between both regimens and purines were restricted during the study period. In both the groups the uric acid levels were reduced (Drisch, 1988).

Effect on Serum Lipids

The effect of the intake of oat on serum lipids was evaluated by Karmally and co-workers (2005). In a randomized controlled trial, two groups of patients (Hispanic Americans) received a corn cereal ($n = 79$) or an oats-containing cereal ($n = 73$) preparation for 11 weeks. The main body mass index of the participants varied between 28.4 and 30.2 (patients with a BMI >38 were excluded). At the end of the treatment period, total cholesterol in the oats group was reduced to 197.3 ± 25.0 mg% from the initial value of 209.0 ± 29.7 mg% while in the corn group there was no change. The difference between both groups was significant. The change in cholesterol level was due to lowering of the LDL cholesterol since the HDL cholesterol was not influenced (Karmally et al., 2005).

In another study 34 premenopausal women (22–53 years) were randomly assigned either to a control group or to a treatment group, which received 2 oat bran-enriched muffins per day (corresponding to 28 g/day of oat bran) for 4 weeks. An increase (11.2%) in plasma HDL-cholesterol was observed in the treated group as compared to the control group. The total cholesterol was decreased by 7.0% (Robitaille et al., 2005). During a 4 week lifestyle program for 235 overweight and hypercholesterolic patients where caloric restriction, fat modification, and oat bran supplementation were part of the nutritional regimen patients were divided into 2 groups with same life style but one group was given 35–50 g oats per day. Male overweight but normocholesterolic subjects ($n = 55$) served as control. In the oat bran enriched food group significant decrease in total cholesterol, mainly due to the influence on the LDL cholesterol, was observed (Berg et al., 2003).

It has been reported that the food matrix or the food processing, or both, could have adverse effects on the hypercholesterolemic properties of oat β-glucan (Kerckhoffs et al., 2003).

Effect on Blood Flow and Blood Pressure

The effect of oatmeal against vitamin C and vitamin E was evaluated by a randomized, placebo controlled, double-blind and cross-over study using brachial artery reactivity scans

(BARS). Oats increased flow mediated vasodilatation measured as percent diameter change before and after treatment (Katz et al., 2004).

It is reported that a diet containing soluble fiber-rich whole oats can significantly reduce the need for antihypertensive medication and improve blood pressure control. It also reduces the body weight (Pins et al., 2002; Saltzman et al., 2001).

Effect on Mental Performance

In a randomized, double-blind, placebo-controlled crossover clinical study, Neuravena, the wild green oat extract, was found to improve the concentration, learning, and alertness during stressful situations (Anonymous: Frutarom, 2008).

Skin Care

Oats are traditionally used for skin care and in various conditions of skin. Studies have been carried out to evaluate the potential of oat in skin care.

A study to evaluate the effect of daily use of products containing colloidal oatmeal derivatives on 300 children was carried out. After 3 months of treatment the cutaneous conditions improved in 76.4% children (Camplone et al., 2004).

In another study colloidal oatmeal was applied to 11 patients with a rash induced by cetuximab, erlotinib, panitumumab, and sorafenib. Out of 10 assessable patients, 6 had complete response and 4 partial responses, with no associated toxicities. Treatment with colloidal oatmeal lotion was considered to be effective in controlling the rash associated with epidermal growth factor positive cancers and tyrosine kinase inhibitors. It allowed continuation of the antineoplastic treatment (Alexandrescu et al., 2007).

Pacifico et al. (2005) had evaluated the efficacy and tolerability of a lotion containing menthol and colloidal oatmeal in patients with itch and cutaneous xerosis by applying the lotion once daily for 3 weeks. Significant improvement of cutaneous lesions including erythema scaling, scratching lesions, lichenization, and pruritus was reported in 52 out of 54 treated patients (96%). Complete regression of cutaneous lesions and pruritus was reported in 88.9% patients whereas partial remission and no improvement were observed in 7.4% and 3.7% subjects respectively.

In another study the safety and efficacy of a cream containing total extract of oat and evening primrose oil was evaluated on 55 patients with atopic dry skin. After 4 weeks of topical application skin dryness, scaling, and pruritus were reported to be greatly improved in almost all cases, and the moisture content of the stratum corneum was also increased significantly. The results of the study revealed that the product was safe and efficient in clinical application for the dry skin of atopic dermatitis, improving the quality of life of patients (Mizuno, 2005).

Oat is reported to protect the skin from irritation which was evaluated from the redness of the skin and cutaneous blood flow (Vie et al., 2002).

A comparative study to evaluate the effect of bath oil containing liquid paraffin with 5% colloidal oatmeal (against liquid paraffin treated control) was carried out in 35 acute burns patients. Patients were asked to rate their discomfort from itch and pain twice daily and the evaluation was made assessor-blinded. The group using the oatmeal preparation showed better result than the vehicle and the requirement of antihistamine medication was significantly less (Matheson et al., 2001).

The corticoid sparing effect of a cutaneous oat extract was evaluated in children with atopic dermatitis and a 42% decrease in topical corticoid use was observed in oat extract group (Grimalt et al., 2007).

Dosage

The Avena herb is used in combination therapy, as a tea for internal use, and in homeopathic mother tinctures and dilutions. The tea is taken repeatedly throughout the day and shortly before going to bed (Wichtl, 1994). Tincture of *A. sativa* fresh herb 3×40 drops per day are recommended for the central nervous system (Van Hellemont, 1985). As homeopathic dosage 5 to 10 drops, 1 tablet, or 5 to 10 globules 1 to 3 times daily, or a 1 mL injection solution twice weekly.

The British Herbal Pharmacopoeia recommends a liquid extract of the seeds (1:1) in 25% alcohol: 0.6–2 mL; and a tincture (1:5) in 45% alcohol: 0.2–5 mL (Anon: British Herbal Pharmacopoeia, 1983). To influence smoking habits, 1 mL of 90% alcoholic extract of *A. sativa* fresh plant diluted with 4 mL of water four times a day has been recommended (Duke and Wain, 1981; Bye et al., 1974).

For cutaneous use a bath of 150 to 200 liters, 60 g Avena flour is prescribed; for children 50% of this dose. U.S.P. 30 (1990) has mentioned the preparation of colloidal oatmeal from the fruits of *A. sativa* (Anonymous: United States Pharmacopoeia, 1990). Colloidal extracts are incorporated in a vehicle (e.g., petrolatum) in a concentration up to 20 to 30%.

Toxicity

Acute Toxicity

The result of a study revealed that an avenathramide enriched mixture did not produce any cytotoxicity to human aortic endothelial cells in concentrations up to 40 μg/mL (Liu et al., 2004). No ocular or cutaneous toxicity was observed in irritation tests using colloidal extracts of *A. sativa*. Sensitization or photosensitization was also not seen up to the concentrations of 2 to 100% (Fabre, 2004).

Sub Chronic and Chronic Toxicity

There are no data available on oral use.

Colloidal Avena extracts are incorporated in different cosmetic formulations such as shampoo, soap, creams, ointments, emulsions, and gels. Colloidal fraction is used externally in bath preparation and for dry skin (Heinrich et al., 2004). These products have been available commercially. These preparations are classified as well tolerated with cosmetovigilance index of $<$0.2/10,000 units (Anonymous: EMEA, 2008).

No data on mutagenecity or carcinogenicity and reproductive toxicity is available.

Contraindications

The use of preparations containing Avena species is contraindicated for persons with a known hypersensitivity to this plant.

Special Warnings / Precautions

Cutaneous Tolerance

Oat preparations are reported to reduce the frequency of allergic reactions in atopic dermatitis and contact eczema conditions (El Bakali et al., 2000; Rance et al., 2001).

Systemic Tolerance

The tolerability of oats in celiac disease children was tested by a double blind multicentred study and oats were well tolerated (Hogberg et al., 2004).

However, another study reported more intestinal symptoms with oats (50 g per day; n = 23) than with a traditional gluten free diet (n = 16) in celiac disease patients. Patients taking oats suffered significantly more often from bowel complaints such as diarrhea and constipation (Peraaho et al., 2004).

Market Preparations

A number of oat products are available in the market. Some of the market preparations are: Quaker, Muscle Milk Oats, Avena Sativa-wild oats, OatWell, Oatrim, Oat Flakes, Oat milk, Granola.

SUMMARY

Avena sativa L., commonly known as Oat, is an annual grass of about 1.5 meters high. It is in use for more than 4000 years as a food and in traditional medicine. Usage of *A. sativa* has been documented since the 12th century. Oats are now cultivated worldwide and its total annual production is around 26 million metric tons. It forms an important dietary staple for the people of many countries. Numbers of varieties of oats are available and depending on the degree of processing they are classified into various types. It is a very nutritious food and used as remedy for various ailments. The oat is rich in protein, has lots of beneficial minerals such as iron, calcium, potassium, magnesium, copper, zinc, silicon, selenium and also number of vitamins like Vitamin B_1, B_2, B_6, B_{12}, Niacin, Vitamin C, Vitamin A, Vitamin E. The presence of these vital minerals and nutrients are useful for strong bones and teeth and also necessary for the maintenance of a healthy nervous system in human being. Different chemical constituents like carbohydrates, proteins, avenanthramides, lipids (9 glycolipids and 11 phospholipids), an indole alkaloid- gramine, number of flavonoids, 3 flavonolignans, saponins, and sterols have been reported from *A. sativa*. Avenacin, a triterpenoid saponins, has been isolated from the roots while Avenacoside A and B are present in leaves. The starch of oat has typical gelatinization characteristics. It contains β-glucan, a mixed-linkage polysaccharide, which is an important part of oat dietary fiber. Oat is the only cereal containing a globulin (water soluble protein), avenalin as a major (80%) storage protein. It also contains avenin, a minor prolamine protein. Oat protein is nearly equivalent in quality to soy protein, which is equal to meat, milk, and egg protein according to WHO. The protein content of the hull-less oat kernel (groat) ranges from 12–24% which is highest among cereals.

Oats are traditionally used as nerve tonic to treat problems like depression, mental debility, and nervous exhaustion. Eating oat is very good remedy when withdrawing from the effects of tranquilizers and antidepressant medications. It is very useful to the people affected by insomnia. Being easily digested, the oat is ideal as a food for the chronically sick patients, for other convalescents, and for mothers recovering from the labors of childbirth. Traditionally, oats have been considered as antispasmodic, antitumor, demulcent, diuretic, neurotonic, stimulant, and tonic. They are useful in rheumatic conditions, in hemorrhoids, lowering high blood pressure, combating obesity, to treat water retention and to regulate the estrogen levels in the body. The fiber content of oat is mainly responsible for lowering blood cholesterol level and helps in combating various cardiovascular diseases. Eating oats is also an excellent remedy for problems like long term irritable bowel syndrome, gastritis, and persistent constipation. Oats have a high content of soluble fiber in the form of β-glucan, and also contain insoluble fibers, arabinoxylans and cellulose. The fibers are not digested in the small intestine, but the soluble β-glucan is believed to increase the viscosity of the food bolus, leading to a slower gastric emptying, enhanced gut fill, and slower absorption of nutrients. The fiber in the oat results in bulkier stools being produced and the bulk is sped faster along the gut, this reduces the exposure time of the sensitive gut lining tissues to various irritants and carcinogens present in the waste. Avenanthramides, antioxidant compounds unique to oats, helps in preventing free radicals from damaging LDL cholesterol and reduces the risk of cardiovascular disease. Oats are also a very good source of selenium, a necessary cofactor

of the important antioxidant glutathione peroxidase. Selenium works with vitamin E in numerous vital antioxidant systems throughout the body and becomes helpful in decreasing asthma symptoms and in the prevention of heart disease. In addition, selenium is involved in DNA repair and is associated with a reduced risk for cancer, especially colon cancer. The consumption of oats is also believed to protect the body against cancer. Oats also lower the blood sugar levels in the body and so the oats, as food, will be helpful to diabetics.

The dried fruits have been used traditionally for the relief of various skin conditions as cutaneous treatments, such as bath preparations, as colloidal extracts of oat flour mixed with a suitable vehicle or as oatmeal in liquid paraffin. The oat herb, harvested before flowering, has also been used traditionally as an herbal sedative usually administered as herbal tea, as aqueous or ethanolic extracts, or as expressed juice from the fresh herb.

Reports of a number of experimental and clinical studies reveal that oat possess wide spectrum of biological activities like antioxidant, antiatherogenic, blood cholesterol (specially LDL-cholesterol) as well as blood sugar lowering effect, in vitro inhibitory activity on MAO-B and PDE-4, topical anti-inflammatory, immunomodulatory, wound healing-properties; useful in asthma, obesity, lowering of uric acid level, controlling blood pressure, skin care, cardiovascular and celiac diseases, provide protection against pre- and post menopausal breast cancer. Those studies substantiate number of traditional claims of oat. The findings of the present review indicate that the use of oat in our daily meal will be very much helpful in the maintenance of health. The potential of oat as preventive as well as therapeutic agent and nutraceutical is promising.

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