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A Complete Review on *Avena sativa*

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Review Article

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ABSTRACT

Background: A cereal is a grass grown for edible components of its grains, source for food, nutraceutical, pharmaceutical components.

Aim: The aim of the present study was to explore the pharmacological, phytochemical, pharmaceutical, nutraceutical, Pre-clinical and Clinical profile of *Avena sativa* L.

Materials and Methods: Different databases such as PubMed, Scopus, Google Scholar, and Science Direct were searched with research papers for documenting different pharmacological and phytopharmaceutical applications of *Avena sativa*, this review creates evidence for its scientific basis. The bioactive molecules of *Avena sativa* include aventhramide, tocols, β-glucan, lignans, anthocyanidins, β-glucan, arabinoxylans and other polysaccharides. The reported clinical data suggest regular consumption of oat will probably reduce the health risks like cardiovascular diseases, chronic obstructive pulmonary disease, and gastrointestinal related health issues.

Conclusion: The review of all clinical results states *Avena sativa* a potential candidate as nutraceutical, and pharmaceutical agent. The advantages seen within clinical studies, but it must well tried in larger studies for far exploration within therapeutic aspect would helpful

Introduction

The word Avena originated from the Sanskrit word “avi,” which means sheep, or “avasa” means food material. The Indian variety is equated with *A. byzantina* C. Koch., *Avena sativa* L. known as oat or common oat is associate degree annual grass concerning 1.5 meters high, culms tufted or solitary, erect or bent at the bottom. The leaves are non-articulate, green; the ligules are blunt and membranous. The inflorescence may be a diffuse raceme with 2–3 florets, all bisexual or the distal one or 2 could also be reduced and male or sterile; glumes sub-equal 7–11 patterned, longer glumes 17–30 mm; lemmas 7–9 patterned, either divided or with a mind their apex; lowest lemma is 12–25 metric linear unit. The rachilla of the cultivated oat doesn't disjoint at maturity (that of many weed species do). Its lemmas are seldom awed. The grain is tightly enveloped by the exhausting lemma and palea. Seed size is found to vary with the variety [1]. Oats are cultivated for two thousand years in varied regions throughout the globe. Oats were originated in England, France, Poland, Germany, and Russia and are currently cultivated worldwide. They need a lower heat demand and larger tolerance of rain than different cereals like wheat, rye, or barley. Oats are associate degree annual plants and may be planted either in season (harvested in late summer) or within the spring (harvested in early autumn). Red oat (*A. byzantine*) is cultivated each in winter and spring. The variation within the chemical constituents in numerous styles of oat has been reported [2, 3]. Betting on the degree of process, oats are classified into varied varieties. Whole oats have a hard-outer hull that has got to be removed for human consumption. Hulled oats are referred to as “groats”. Instant oats are created in an exceedingly similar approach like rolled quick-cooking oats, except they're steamed longer amount and rolled additional thinly. Oat flour is obtained by grounding the oats and frequently out there in 3 grades: coarse, medium, and fine [3, 4]. Oats are employed in varied ways that in food like whole grains, meal, crushed into oatmeal or ground into oat flour. Oats used as a cereal, are healthier referred to as a breakfast cereal, used whole or as a meal in cold cereals like breakfast food or dry cereal. Oat flour is employed in creating biscuits, sourdough, etc. it's not appropriate for creating bread because it lacks protein at flour is employed as an associate degree inhibitor in food merchandise and a few vegetable oils because it inhibits rancidity and will

increase the length of shelf-stability of fatty foods and vegetable oils. Edible oil obtained from the grains is employed within the manufacture of breakfast cereals [5].

Taxonomic information [6,7]

Kingdom	:	Plantae
Super division	:	Spermatophyta
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Cyperales
Family	:	Poaceae
Genus	:	Avena
Species	:	*A. Sativa*

Common Names

Oat, Cultivated Oat, Oats, Side Oat, Tree Oat, Red Oat

Vernacular Names

India	:	Gandal, Ganer, Jai, Jayee, Sanskrit: Atiyav Mundyav
Indonesian	:	Gandum
Arabic	:	Hartaman, Shufan
Brazil	:	Aveia
German	:	Echter Hafe, Futterhafer
Africa	:	Hawer, Hawermeel
Bulgarian	:	Obec
China	:	Yan Mai Shu
French	:	Avoine, Avoine commune
Italian	:	Avena, Biada, Gramigna

Pharmacological functions

Studies showed that oat induces varied health benefits, as well as aid in weight loss, lower blood glucose levels and reduced risk of cardiopathy [8, 9]. The following table details the pharmacological actions shown by the *Avena sativa* (Table 1).

Phytoconstituents:

Phytoconstituents like carbohydrates, proteins, tocols, lipids, alkaloids, flavonoids, saponins, and sterols have been reported from *A. sativa* (Table 2), (Figure 2).

Carbohydrates

Oat grain contains about 25–30% amylase and therefore has typical gelatinization property. In cool condition oat starches become more elastic, clearer and more adhesive [28]. β-glucan is the main part of oat dietary fiber [29].

Proteins

Oat is the only the cereal that contains the globulin or legume-like protein, avenalin, which is a high (80%) storage protein. Avenin, a prolamines is a minor protein in oat. Some proteins are disulfide-linked α and β-isomers which are unreduced heterogeneous proteins having molecular weight 53000–58000 [30]. The protein content of oat ranges from 12-14%, higher than the other cereals. According to WHO, oat protein is equal to that of milk, meat, and egg protein. The quality of oat protein is also equivalent to soy protein [31].

Lipids

Oats contain lipids like triglycerides, free fatty acids, phospholipids, glycolipids, steryl esters, and partial glyceride [32]. It contains phospholipid lecithin (45–51%) in a major amount [33-35].

Alkaloids

Two types of alkaloids have been reported in oats that are indole alkaloid and avenanthramides. Indole alkaloid, gramine isolated from *A. sativa*. *Avena sativa* has a slight sedative effect [36]. Avenanthramides are basically phenolic alkaloids [37-39] (Figure 1).

Tocols

Oats exhibit antioxidant capacity owing to the presence of tocols, in particular α- Tocopherol which is abundant component [21]. Tocotrienols, β-tocopherol, γ-tocopherol, δ-tocopherol, α-tocotrienol, β-tocotrienol, γ-tocotrienol, δ-tocotrienol have also been reported in oats [40].

Organic Acids

Organic acids like aconitic, malonic, maleic, oxalic, citric acid, caffeic, ferulic acids have been reported in fruits while avenic acid A and B have been reported in the green herb of *A. sativa*. Avenalumic acids have also been reported from oat groats and hulls [38, 41]. The sucrose di-ester of a substituted β-truxinic acid has also been reported [42, 43].

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Table 1: Pharmacological activities of *Avena sativa.*

S. No.	Pharmacological activity	Reference
1.	Gastro protective effect against gastric ulcer	Anila Kanwal et al., 2018 [10]
2.	Atopic dermatitis	Fowler JF 2014 [11]
3.	Wound healing	Rania EL Hosary et al., 2020 [12]
4.	Cosmetics	Lillian C. Becker et al., 2019 [13]
5.	Anti-Hyperlipidaemia	· Ibtsam M. Gheith et al. 2019 [14]
6.	Hepatoprotective action	Trishna Debnath et al., 2018 [15]
7.	Cognitive function improvement Anti-depressant activity Anxiolytic effect	David O. Kennedy et al., 2020 [16] Usha Rani et al., 2014 [17]
		Kaur D et al., 2016 [18]
8.	Anti-obesity	Salwa M et al., 2018 [19]
9.	Anti-tumour effects	Fu, R. et al., 2019 [20]
10.	Anti-inflammatory	Rikard Landberg et al., 2020 [2]
11.	Vasodilatory effect	Lin Nie L et al., 2005 [21]
12.	Cytoprotective effect	Na Lv et al., 2009 [22]
13.	Nutraceutical	Muhammad Suhail Ibrahim et al., 2020 [23]
14.	Anti-diabetic	Shengmin Sang et al.2016[24] Li-xia He et al., 2016 [25]
15.	Anti-epileptic, Anti-addictive	E. Carminati et al., 2019 [26]
16.	Anti-fungal, Anti-Candidiasis	H. Sørensen et al., 2010 [27]
17.	Anti-Fibrotic, Anti-Gout,	Sing et al., 2013 [1]

Table 2: Phytocompounds from Avena sativa.

Phytoconstituent	Class
Quercetin, Catechin, Kaempferol, Caffeic acid, Syringic acid, Ferulic acid, Rosmarinic acid, Naringenin, Amentoflavone, Myricetin	Phenolics/Flavonoids
Avenanthramides, Gramine	Alkaloids
β-glucan	Carbohydrates
β-Sitosterol, Campesterol, Campesteryl ferulate, Sitosterylf erulate, Sitosteryl glucose	Sterols
Campestanol, Campestanyl ferulate, β-Sitostanol,	Stannols
Sitostanyl ferulate, Sitostanyl glucose	
α-tocopherol, β-tocopherol, γ-tocopherol, δ-tocopherol	Tocols
Lutein, α-carotene, β-carotene	Carotenoids
Pinoresinol, Mediresinol, Syringaresinol, Larciresinol, Secoisolariciresinol, Matairesinol	Lignans
Cyanidin-3-galactoside, Cyanidin-3- glucoside	Anthocyanins
Avenacin, Avenacosides A & B	Triterpenoid saponins

Flavonoids

Quercetin, kaempferol, naringenin, and amentoflavone present in oats. Luteolin-6-C-glucoside, luteolin- 6-C-glucosyl-arabinoside, apigenin-6,8-di-C-glucoside, apigenin-8-C-arabinosylhexoside, apigenin-6-C-glucoside, apigenin-6-C-glucosyl-arabinoside, apigenin-8-C-rhamnosylglucoside, are flavone C-glycosides found in oats. Literature indicated the presence of Isoorientin-2-O-β-D-diglycoside, isoorientin-7-O- β-D-glycoside, isoorientin, isoorientin-2-O-arabinoside, isoorientin, 4,5-dihydroxy-7-methoxy-8-C-glucosyl-O-rhamnoside, isoswertisin-2-O- α-L-rhamnoside, isoswertisin-2 –rhamnoside, 7-methoxy-vitexin-O-rhamnoside, tricin-4-O- β-D-glycoside, tricin-7-O- β-D-glucoside, vitexin- 2-rhamnoside in oats. Tricin is an O-methylated flavone also present in oats [44, 36]. Rhamnosylisoswertisin protect the plant from mycoses because of its phytoalexin properties. O-methyl-apigenin C-deoxyhexose-O-hexoside, obtained from oat, protect against major cereal nematodes, Hetrodera, and Pratylenchus [45]. Oat herb contains three flavonolignans in which two are diastereomeric flavonolignans- tricin 4-O-(threo-α-guaiacylglyceryl) ether and tricin-4-O- (erythro- a-guaiacylglyceryl) ether mentioned as salcolins A and B, respectively [36] (Figure 3).

Saponins

Several types of saponins like triterpenoid saponins, avenacosides A and B from the leaves, and avenacin are reported from the root of *A. Sativa* [46, 48]. Leaves have acylated and steroidal saponins, sterylglycosides (ASG), sterols, sterylglycosides (SG). Oats possess sterols like stigmasterol, stigmasterol, campesterol, campestenol, cholesterol, sitosterol, cholestenol, 5-avenasterol, 7-avenasterol, lophenol7stigmastenol, and 7- cholestenol [39, 49].

Nutraceutical and Pharmaceutical functions:

Oats perceived as a nutraceutical and pharmaceutical key player owing to its plentiful dietary elements, and many nutritional components. Oat's usage promotes health, reduces bad cholesterol and the risk of cardio vascular diseases. Considering these properties, oats have crucial noteworthiness in humans too [50-53].

Fibers

Oats contain both soluble (β-glucan) and insoluble fibres (fiber-arabinoxylans and cellulose). It has been reported that regular use of oat in a diet with high fiber controls and prevents various diseases [54]. The physiological responses are mediated via insulin

and gastrointestinal hormone secretion [55]. This has been reported that β-glucans have cholesterol-lowering property. Daily intake of about 3 g of soluble fibre from oat with low saturated fat and cholesterol diet may reduce the risk of heart disease. FDA has allowed to made health claims on the labels of food holding soluble fibers from whole oats but whole oat holding food must give 0.75 grams of soluble fibre [56, 57].

Oat bran, rolled oats, and other oat products have enough β-glucans to be favourable to health. Several studies have been reported the valuable role of oat in controlling cholesterol, blood pressure, arterial health, and insulin level. Cereal products for their strong hypocholesterolemic properties have been recommended recently as healthy food. The Oatrim™, a fat replacer fused the activity of typical dietary fibers with prebiotic activity [58]. Cholesterol reducing property in hypercholesterolemic patients decreasing the risk of heart diseases has been reported [50]. The mechanism is still not clear. It has been demonstrated that the role of viscosity alteration in digesta is valuable because it enhances intestinal viscosity, which may reduce the absorption of cholesterol and the reabsorption of bile acids. According to the FDA, the use of oat β-glucan containing dietary fiber decreases the glycemic and cholesterol responses of individuals, 20–30 g/day of total dietary fiber is the suggested intake by the National Cancer Institute. β-glucans stimulate immune responses by the alteration in short chain fatty acid production by the microflora [52, 59].

Lipids

It contains more than 10% lipid as compared to about 2–3% in wheat and most other cereals (maize- 17%). The polar lipid content of oats which is about 33% that is 8–17% glycolipid and 10–20% phospholipid is more than that of other cereals [60]. Lipids are rich in lecithin. It is a phospholipid that contains 45–51% lecithin [33].

Proteins and amino acids

Oat is the one cereal containing a legume-like protein (globulin), avenalin (80%), a storage protein. Globulins are identified by water solubility and they may be converted into milk but not into bread. The more distinctive cereal proteins such as gluten and zein are prolamines. Avenin, a prolamine protein that is present in fewer amounts in oats. The properties of oat protein are almost equivalent to soy protein which, according to WHO is equal to meat, milk, and egg protein. The protein content of the oat ranges from 12–24%, which is highest than other cereals [61]. Glutamic acid is present predominantly in oats flour while glycine and alanine are present in lower amounts [62] Protein content (g/100 g) and amino acid profile (g/100 g protein) sprouted oat powders (Table 3).

Vitamins

Oat contains both water and fat-soluble vitamins [1, 63]. Vitamin B_1 (0.002%), vitamin B_2 (0.001%), vitamin B_3 (0.032%) and vitamin E (0.84%) has been reported in oats. The vitamins content in seeds are given in [Table 4].

Mineral Substances

Oats are also rich in mineral content and the mineral content differ according to the region. Oat seed powder consists of considerable amounts of both major and minor minerals, being K the main mineral, followed by P, Mg, and Ca. The micro-minerals Fe, Zn, and Mg were also present enough quantities, while Na and Cu were the minor minerals (Table 5).

Clinical and Pre-clinical studies

Antidiabetic Activity

Foods yielding low postprandial glycemic responses have been suggested to be beneficial for the dietary prevention of type 2 diabeteS [64]. The soluble fibre β-glucan from the oats can decrease the glycemic response [65]. The high molecular weight of β-glucan increases the fluid viscosity in the intestine, it is crucial for obtaining the positive effect of β-glucan on the peak blood glucose level [29]. 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 [66]. 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 [65,67]. Oats 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 [68]. 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 in take 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 [69]. Daily consumption of low-fat dairy foods was also helpful in lowering the risk of type 2 diabetes by 13%.

Cardiovascular Diseases

High fiber foods, such as oats, help in preventing heart disease [70]. 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

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Table 4: Vitamin content of Oats.

Vitamins	:	Content
Vitamin A	:	0.862 mg/100 g
Vitamin B1/thiamine	:	3.89–7.07 mg/kg
Vitamin B6	:	56 nmol/g
Vitamin E/ tocopherol	:	0.5 –1.0

Table 5: Mineral composition of *Avena sativa.*

Average Macronutrient mineral (wt%)		Average Micronutrient mineral(mg/kg)	
Minerals	**Content**	**Minerals**	**Content**
K	1.84± 0.21	*Zn*	26.4± 2.1
Ca	0.12± 0.04	*Cu*	14.8± 1.3
Mg	0.16± 0.05	*Fe*	26.4± 2.4
N	2.41± 0.45	*Mn*	16.9± 1.7
P	0.32± 0.09	*Mo*	3.68± 0.45
S	0.12± 0.03	*B*	14.9± 2.63

Table 3: Protein composition of Oats.

Protein		**10.73 ± 0.26**	
Non-essential amino acid		Essential amino acid	
Sprouted oat powder		Sprouted oat powder	
Asp	6.36 ± 0.02	His	1.62 ± 0.13
Glu	11.85 ± 0.10	Val	3.06 ± 0.01
Ser	4.11 ± 0.68	Met	0.81 ± 0.01
Gly	4.02 ± 0.27a	Cys	1.32 ± 0.03
Arg	1.41 ± 0.19	Ile	1.63 ± 0.19
Ala	4.43 ± 0.3	Leu	3.27 ± 0.60
Pro	3.26 ± 0.03	Phe	2.02 ± 0.12
		Tyr	0.34 ± 0.10
		Lys	3.42 ± 0.03
		Thr	2.21 ± 0.02
		Trp	1.69 ± 0.11
		Total	22.44 ± 2.78

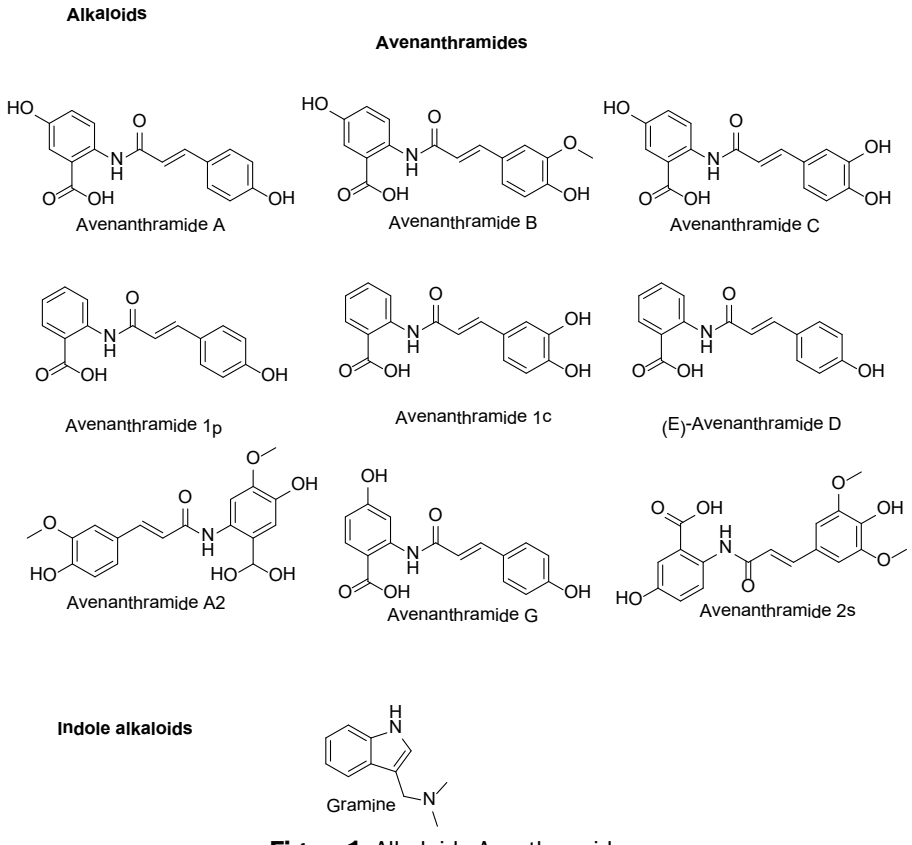

Figure 1. Alkaloids-Aventhramides.

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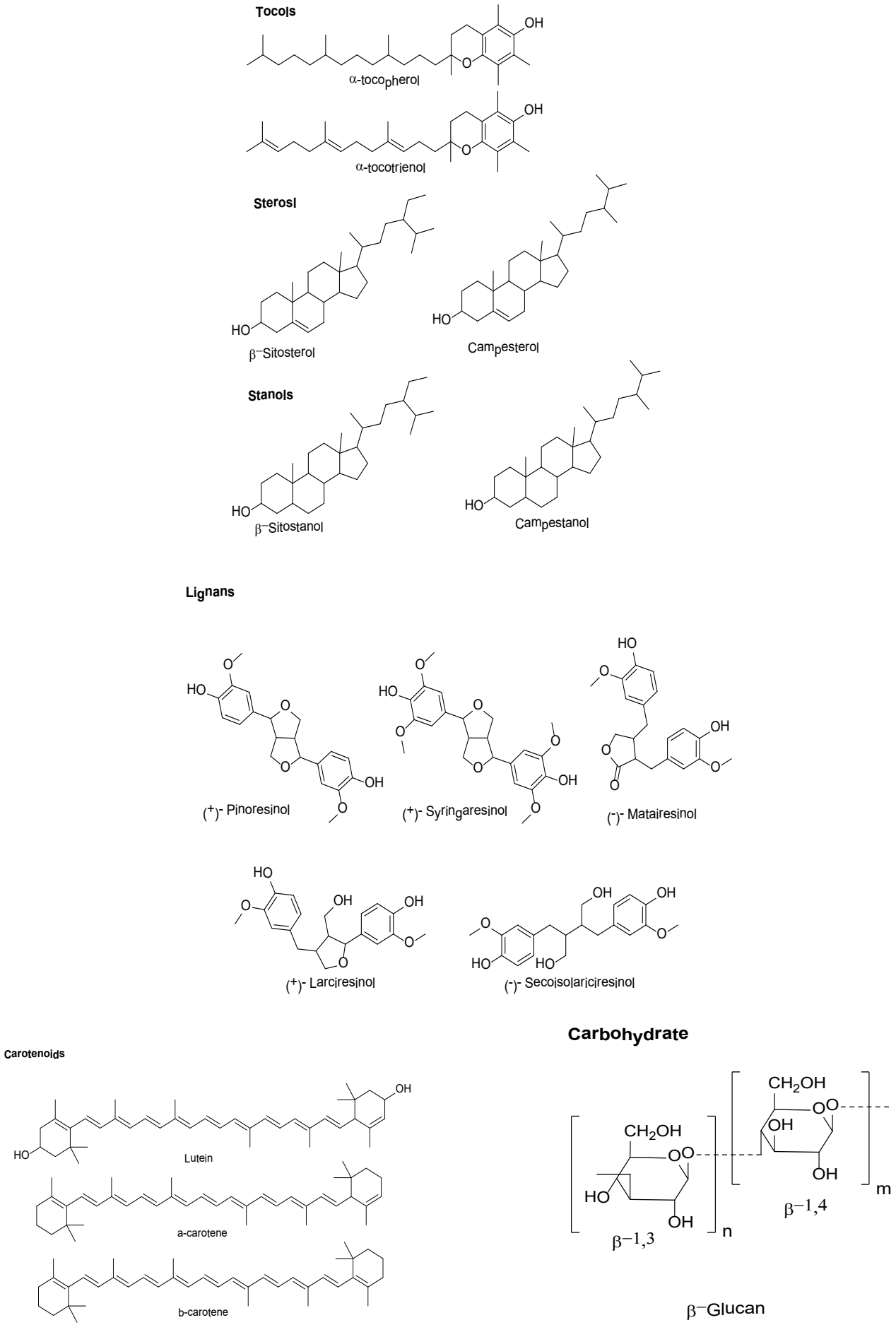

Figure 2. Phytoconstituents from Avena sativa.

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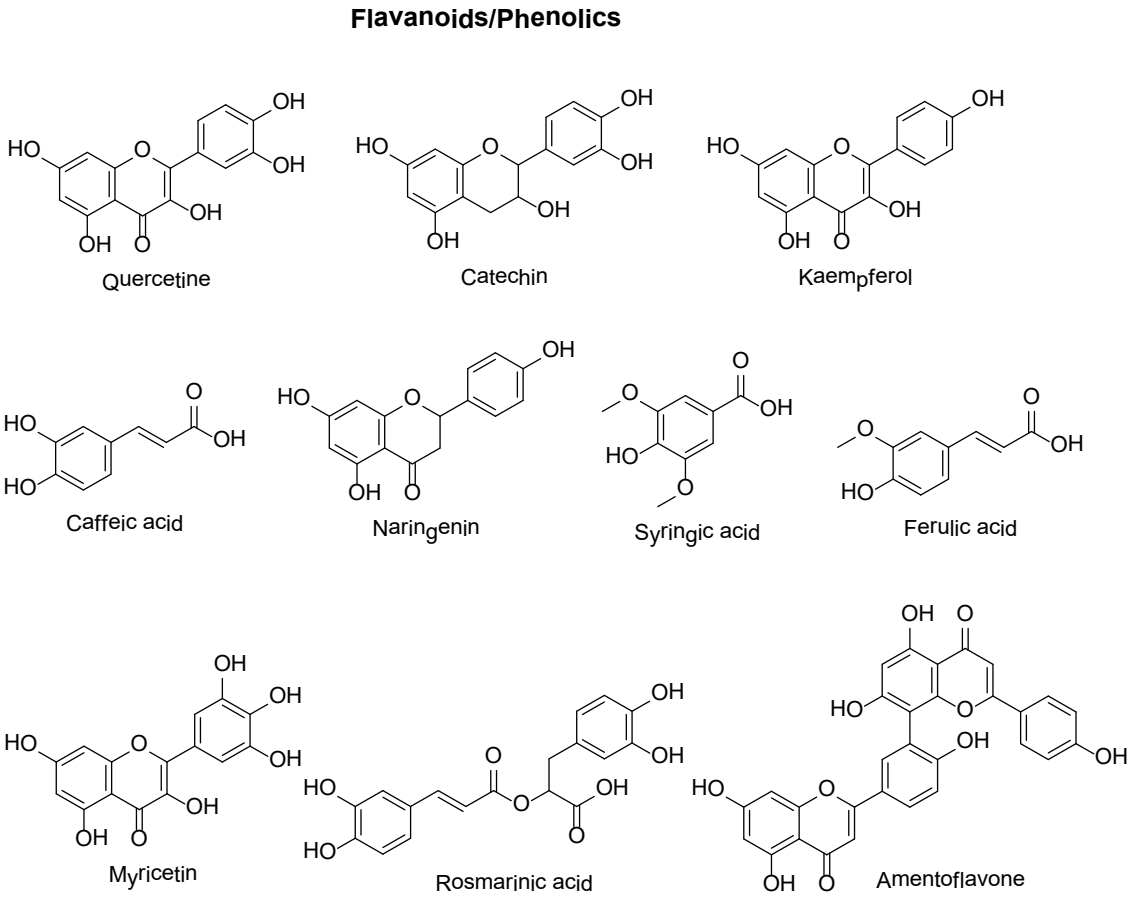

Figure 3. Flavonoids & Phenolics.

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. 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 [71] 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 [72,73].

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 diarrhoea, 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 [74]. A number of studies have suggested that the ingestion of oats is safe [75-78]. 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 [79].Number 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 [80].

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 [81]. 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. Premenopausal 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 [82]. 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% [83]. 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.

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 [84-86].

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 was 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 [87]. 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% [88]. 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 similar lifestyles 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 [89]. 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 [90].

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. Oats increased flow mediated vasodilatation measured as percent diameter change before and after treatment [91]. 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 [92]. Neuravena, the wild green oat extract, was found to improve the concentration, learning, and alertness during stressful situations.

Skin Care

Oats are traditionally used for skin care. 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 [93]. 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 effective in controlling the rash associated with epidermal growth factor positive cancers and tyrosine kinase inhibitors. It allowed continuation of the antineoplastic treatment [94, 95] 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 [96]. Oat is reported to protect the skin from irritation which was evaluated from the redness of the skin and cutaneous blood flow. 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 results than the vehicle and the requirement of antihistamine medication was significantly less [97]. 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 [98].

Gastroprotective effect against gastric ulcer

A. sativa shows gastroprotective effect in gastric ulcers. A peptic ulcer is an inflammatory disorder of the bowel. Caused due to the development of sores inside the mucosal layer of the stomach and upper portion of the small intestine that is the duodenum. A peptic ulcer involves gastric and duodenal ulcers. Due to heavy acid secretion, the mucosal layer of the stomach gets disturbed and causes inflammation which leads to peptic ulcers.

Butanol fraction of *A. sativa* has potent gastroprotective activity against peptic ulcers by inhibiting the inflammatory mediators. It also inhibits Cyclooxygenase (COX) and lipoxygenase (LOX) enzymes have been reported. Alkaloids of *A. sativa* like avenanthramides have antiulcer activity. They reduce the H+ Concentration in the stomach and increases pH in gastric content. Saponins of *A. sativa* have also antiulcer activity by stimulating the defensive mechanism of mucus membrane and by inhibition of PGF2α it decreases the gastric secretion

Antiulcer activity of seeds grains of *A. sativa* powder on male albino rabbits at graded doses has been reported. The efficacy was a measure based on ulcer scores, ulcer index, acid output, pH, curative ratio, and gastric secretions. In the first group, they had to give indomethacin which results in an increase in all these factors, and when they gave ranitidine with indomethacin all these factors get decrease and shows antiulcer activity. A similar effect was found with indomethacin and *A. sativa* at a dose of 750 mg/kg [10].

Atopic dermatitis

Atopic dermatitis is a skin disease which includes itchy and red skin. Colloidal oatmeal is used for atopic dermatitis. FDA has announced that colloidal oatmeal is safe and effective ingredients. It is used in inflammatory skin diseases. Colloidal oatmeal used in bath soap, shampoos, moisturizing creams, shaving creams, and other cosmetic products. The water-holding and skin-protecting property of colloidal oatmeal is due to the high concentration of starches and β-glucan. Colloidal oatmeal showed atopic activity by inhibition of inflammation and antioxidant property. Avenanthramides, vitamin E, ferulic acid, and other antioxidants have anti-inflammatory and antioxidant activity which is responsible for atopic dermatitis. It has been reported that avenanthramides at low doses that are as low as one ppb decrease the phosphorylation of the p65 subunit of NF-kappa B and it also inhibits TNF-α and IL-8. In this way, it reduces inflammation [11].

Wound healing

β-Glucan is most abundantly present in A. sativa. It is a polysaccharide glucose polymer. β-glucan has the property to stimulate tissue granulation, biosynthesis of human dermal fibroblast collagen, deposition, and re-epithelialization which is responsible for wound healing activity. The wound healing property of PVA-biopolymer composite hydrogels of A. sativa has been reported [12, 99].

Anti-Hyperlipidaemia

The aqueous *A. sativa* mucilaginous seed extract lowers cholesterol. It is a good anti-hyperlipidaemic agent. β-glucan from oat bran reduces cholesterol. The anti-hyperlipidaemic activity has been studied on high fat diet albino rats. Administration of aqueous-mucilaginous seed extract of A. sativa to rats that kept on a high-fat diet resulted in decreases elevated lipids, tri-acylglycerols, cholesterol, LDL-C, VLDL-C, & normal serum HDL-C Concentration seed extract used to control dyslipidaemia in rats that prepared as a hyperlipidaemic model by high-fat diet supplementation [14].

Antidepressant activity

The in-vivo antidepressant activity of methanolic seed extract of *Avena sativa* (MSEAS) has been reported [17]. The methanolic seed extract of *Avena sativa* includes alkaloids, flavonoids, glycosides, saponins, steroids, amino acids, gums, carbohydrates, and mucilage. The anti-depressant activity has been evaluated based on behavioural models like Forced swim test (FST), Tail suspension test (TST).

These tests were sensitive and specific to all major classes of Antidepressants. FST&TST reflects a state of despair or lowered mood, which are thought to reflect depressive disorders. This in-vivo study has carried out on Swiss male albino mice. They induced hypothermia to Swiss male albino mice by antagonism effect of apomorphine, and daily administered MSEAS 100 and 200 mg/kg, p.o for 7 days. The standard antidepressant drug in behavioural models used was Fluoxetine 25mg/kg p.o and Desipramine20mg/kg p.o in Apomorphine induced hypothermia. The methanolic seed extract of *Avena sativa* shows a significant

antidepressant activity in both FST and TST as they decrease immobility. It reverses the hypothermia produced by apomorphine. The study has demonstrated that the antidepressant effect might be due to the flavonoids. Mechanism of action involves the two doses of MSEAS (100 &200mg/kg, p.o) and Desipramine (20mg/kg, p.o) significantly antagonized the Apomorphine induced hypothermia (16mg/kg, sc).

Depression involves the imbalance between the three neurotransmitters are noradrenaline serotonin and dopamine, in depression level of these three neurotransmitters lowers. An Antidepressant medication increases the level of these neurotransmitters. Study shows that MSEAS has acted through the adrenergic system, but it doesn't influence the serotonergic system.

Lethal dose found to be up to the level of 2000mg/kg, p.o during acute oral toxicity study, and the antidepressant activity of methanolic seed extract of *Avena sativa* was found to be at low doses (100mg/kg, p.o).Study shows that the methanolic seed extracts flavonoid compounds of *Avena sativa* has the antidepressant effect acting through the adrenergic system [17].

Hepatoprotective action

Oat bran is the by-product produced during the oat grains processing. Oat bran extract has hepatoprotective activity. Liver damage occurs due to over production of reactive oxygen species (ROS) and lipopolysaccharides. Oat bran extract contains phenolics/ flavonoids, organic acids, and vitamin E, and other antioxidants which reduce oxidative stress on the liver and also Avenanthramides that inhibits the secretion of inflammatory mediators like TNF-α, ILs [15].

Cognitive function improvement

The cognitive function improvement property of green oat extract has been evaluated clinically. Wild green-oat extract (GOE) inhibits the enzymes monoamine oxidase-B (MAO-B) and phosphodiesterase 4 (PDE 4), responsible for the degradation of neurotransmitters like noradrenaline, dopamine, and serotonin (5-HT), and cyclic AMP. The neurotransmitters play an important role in cognitive function and mood. The extract consists of a variety of potentially bioactive compounds, including flavonoids, triterpene saponins, phosphatidylcholine, choline and, organic acids, and amino acids. These bioactive compounds have a wide variety of cellular and physiological effects and improve brain function and cognitive performance in humans [16].

Anti-tumour effects

Avenanthramides extracted from oat bran have anti-tumour effects. Colorectal cancer (CRC) is a malignant gastrointestinal tumour with high mortality throughout the world. CRC is often treated by targeting the mitochondria of the tumour cells. Avenanthramides target the mitochondria, leading to mitochondrial bioenergetics collapse and ROS-dependent apoptosis in colorectal cancer (CRC) cells. In oat extract, Avenanthramide A (AVN A) is a main active compound, which binds to DDX3 protein, an ATPase-dependent RNA helicase, which is the main regulator of mitochondrial translation and tumour progression. AVNA binds with Arg-287 and Arg-294 residues of DDX3 to inhibit its ATP hydrolysis property and stability of the protein [100].

Anti-inflammatory

Avenanthramides have potent anti-inflammatory activity by inhibiting the lipoxygenase (LOX) enzyme LOX catalyses the oxygenation of polyunsaturated fatty acids (PUFA) into potent inflammatory mediators, leukotrienes. The mechanism of LOX inhibition can be explained in various ways, e.g., the inhibitor may oxidise the linoleic acid radicals formed, it may chelate or decreases the Fe3þ ion in the active site of the enzyme, or it may interact with the enzyme molecule. Research has demonstrated that the anti-inflammatory activity of Avenanthramides might be due to inhibition of LOX enzyme and antioxidant ability [2].

Vasodilatory effect

Oats consist of avenanthramides and Phenolic alkaloids. Avenanthramide-2c, is one of three major avenanthramides in oats, consist of about one-third of the total avenanthramide concentration in oat grain, and this has the highest antioxidant activity reported in *in-vitro* studies. The bioavailability study of avenanthramides has been carried out on hamsters and recently in humans. Synthetically prepared avenanthramide-2c, is effective in reducing mitogen-stimulated smooth muscle cells (SMC) proliferation and enhances Nitric oxide production which is responsible for vasodilator activity by smooth muscle cells (SMC) and human aortic endothelial cells (HAEC) in an in vitro cell culture system has been studied. Collectively these findings suggest a regular diet of oat might reduce the risk of heart disease [21].

Cytoprotective effect

Oats and oatmeal are used to treat inflammatory diseases it contains Avenanthramide. Several derivatives of Avenanthramide have been synthesized. One of them Di-hydro-avenanthramide D (DHAvD), which is the active component in oats. The cytoprotective activity of Dihydro avenanthramide D has been reported. In type 1 diabetes Beta cells of the pancreas which are involved in insulin synthesis are damaged due to two major reasons that are Cytokines and streptozotocin-induced β-cell damage. A recent study had shown that avenanthramide that is DHAvD could prevent cytokine or streptozotocin (STZ)-induced pancreatic b-cell damage using cultured RINm5F cells, isolated islets, and an STZ-induced diabetes animal model. Additional studies are required to establish whether DHAvD affects ROS production in pancreatic b-cells or not. The studies reported that avenanthramide has enhanced or suppresses Nitric Oxide production according to their target cells or avenanthramide used. It is observed that cytokine-induced Janus Kinase/Signal Transducer and Activator of Transcription (JAK-STAT) phosphorylation were partially inhibited by DHAvD. As reported, interruption of the JAK-STAT pathway is an effective way to protect against the deleterious effects of cytokines on b-cells. DHAvD has a protective effect against cytokines through suppressing both NF-jB and JAK-STAT pathways [37].

ACE inhibitor

The potential peptide produced from oat proteins by enzymatic hydrolysis. It has potent antihypertensive properties by inhibiting angiotensin- I converting enzyme in rennin angiotensin aldosterone system that involves in blood pressure regulation [101].

Antifungal activity

Methanolic crude extract of oats containing flavone-C-glycosides inhibit the growth of Pyrenophora species. Previous studies indicated that 26-desglucoavenacoside B and 26-desglucoavenacoside A are active antifungal compounds released by deglycosylation of avenacoside A and B in infested leaves. 26-desglucoavenacoside B shows the greatest inhibition of pyrenophora mycelia while 26-desglucoavenacoside A and avenacosides A and B showed minor inhibition of the mycelia growth. The specificity of the flavone-C-glycoside, 0-methylapigenin- C-deoxyhexoside-0-hexoside as an antinematode compounds and the saponin, 26-desglucoavenacoside B as an anti-pyrenophora fungicide, suggests these compounds can be used to target particular organisms [102].

Chronic kidney disease

Literature studies on oat intake have been found beneficial effects on kidney function. Rouhani M. H. [103] reported that the effect of oat intake on renal function in patients with chronic kidney disease (CKD). Fifty-two patients with CKD were randomly taken, in that they made two groups, each group involves 26 subjects. Patients were randomly taken for nutritional recommendations and nutritional recommendations 50 grams of oat flour per day. A control group recommended reducing the intake of dietary protein, phosphorus, sodium, and potassium. The time for this study was 8 weeks. Parameters like blood urea nitrogen (BUN), serum creatinine (SCr), urine creatinine, serum albumin, serum potassium, parathyroid hormone (PTH), and serum klotho and urine protein concentration were measured at baseline. According to the researcher's hypothesis, oats have favourable effects on inflammation, oxidative stress, and lipid profile of patients with CKD [104].

Antioxidant property

Oats contains Avenanthramides (AV), which might reduce the risk of cardiovascular disease. The randomized, placebo-controlled, 3-way crossover trial has been carried out for antioxidant action of avenanthramide A, B, and C in healthy older adults and pharmacokinetics. With 1-week washout periods. The bioavailability of AV-A was 4-fold more than that of AV-B at the 0.5 g avenanthramide-enriched mixture dose. In a placebo-controlled, 3-way crossover study with a 1-wk washout period between treatments, the subjects were randomly selected to consume 360 mL skim milk alone (placebo) or containing 0.5 or 1 g avenanthramide-enriched mixture extracted from oats. The avenanthramide-enriched mixture was not soluble in skim milk, residual avenanthramide consumed by each subject. Each subject was treated and placed in the Metabolic Research Unit in the morning after a 12-h overnight fast. Monitoring of vital signs, plasma samples were taken in a 10-h period. After drinking the test beverage in; 5 min, 8 blood samples were collected at 15, 30, and 45 min and at 1, 2, 3, 5, and 10 h. dietician recommended low flavonoid content and dietary allowances for protein and energy for lunch and dinner. These meals were provided at 4 and 9 h after consumption of the avenanthramides. Food and other beverages were not allowed during the test period, but the consumption of water, salt, sugar, and ginger ale was allowed.

In this clinical trial showed that three avenanthramides, were bioavailable in humans but avenanthramides-A was the most bioavailable. Avenanthramides and other avenanthramide-enriched mixture constituents after a single oral administration increase some antioxidant defences in vivo by increasing GSH status and acting in synergy with other antioxidants such as vitamin E. As bioavailable and bioactive phytochemicals, avenanthramides and other avenanthramide-enriched mixture constituents may have health benefits [105].

Conclusion

Avena sativa has emerged as a nutraceutical agent due to its high nutritional value. A perusal of clinical studies encourages the dietary use of *A. sativa*. The daily intake of oats, a rich source of dietary fibers is an extremely effective strategy in reducing risk of hypertension, obesity, diabetes. The presence of variety of phytoconstituents makes it a very important source of herbal formulation. However, strong investigation on the mechanism of action and toxicity profile of this natural source still needs to be done. The clinical studies are needed to be performed on a larger scale. The popularity of *A. sativa* continues to grow and much more scientific investigations can be performed.

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