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Oats: Understanding the science

[1] Preeti Khanna, [2] Sumit Mohan

[1] Senior Research Fellow (Ph.D Scholar), Delhi University, Delhi, India
[2] AGM New Product Development, DS Group, Uttar Pradesh, India

Abstract
This article is intended to focus on the composition and the nutritional benefits (health claims) of oats. Oats have a distinct and multi funtional nutritional profile. Recent researches have established the therapeutic properties of its components. Oat β-glucan (OβG) consists mainly of the linear polysaccharide (1→3), (1→4)-β-D-glucan and is often called β-glucan. This soluble oat fiber is able to attenuate blood postprandial glycemic and insulinemic responses, to lower blood total cholesterol and low-density lipoprotein (LDL) cholesterol, and to improve high-density lipoprotein (HDL) cholesterol and blood lipid profiles as well as to maintain body weight. Thus, intake of OβG intake is beneficial in the prevention, treatment, and control of diabetes and cardiovascular diseases. The health benefits may be attributed to it's physicochemical properties (such as viscosity, molecular weight) which can be affected by extraction methods and its behavior in gastrointestinal tract. Oats and it's by products (like oat bran) have proven to be helpful in the treatment of diabetes and cardiovascular disorders. Oat bran is a concentrated source of b-glucan and also is a good source of B complex vitamins, protein, fat, minerals. The b-glucan has outstanding functional properties and is of immense importance in human nutrition.

Keywords: Oats, β-glucan (OβG), Dietary Fibre, Cholesterol Management, Weight Management, Heart Health, Diabetes Management, Aventhramides, USFDA

Introduction
Oats have earned the title of a "Supergrain" because of the health benefits they provide. In addition to soluble fibre, polyphenols & avenanthramides (antioxidants), oats and oat products have many bioactive compounds that may provide health benefits. Oats and oat-containing products that meet a minimum level of oat beta-glucan are allowed to bear a FDA-approved health claim for cholesterol-lowering benefits.

Oat, like all other grain varieties, belongs to the Poaceae family and is known as ''Jai'' or ''Javi'' in Indian subcontinent. The common oat (Avena sativa) is species of cereal grain mainly grown for its utilization for human consumption as oatmeal as well as for livestock feed. Oat has always been regarded as a health promoting food without clear knowledge of its specific health related effects. However, today it is known for its effects on satiety and retarded absorption of nutrients as well as a deterrent of various disorders of the gastrointestinal tract. These beneficial effects are chiefly due to the soluble fiber content of oats. Today oats is among the richest and most economical sources of soluble dietary fiber The present interest in soluble oat fiber originated from reports that showed that dietary oats can help in lowering cholesterol (Hsing-Hsien and Ming-Hoang 2000; Bae *et al.*, 2010; Drozdowski *et al.*, 2010; Tiwari and Cummins 2011) [21, 3, 11, 40], postprandial blood glucose level (Wood *et al.*, 2000; Hooda *et al.*, 2010; Regand *et al.*, 2011; Dong *et al.*, 2011; Tiwari and Cummins 2011) [45, 40, 18, 20, 34, 10, 40] as well as modifying immune response and reducing risk of colon cancer (Malkki 2001; Yang 2008).

Fig.1 explains the processing of oats. Depending upon the processing parameters, various commercial end products of oats are available (Fig.2) with distinctive sensory properties (Table 1.)

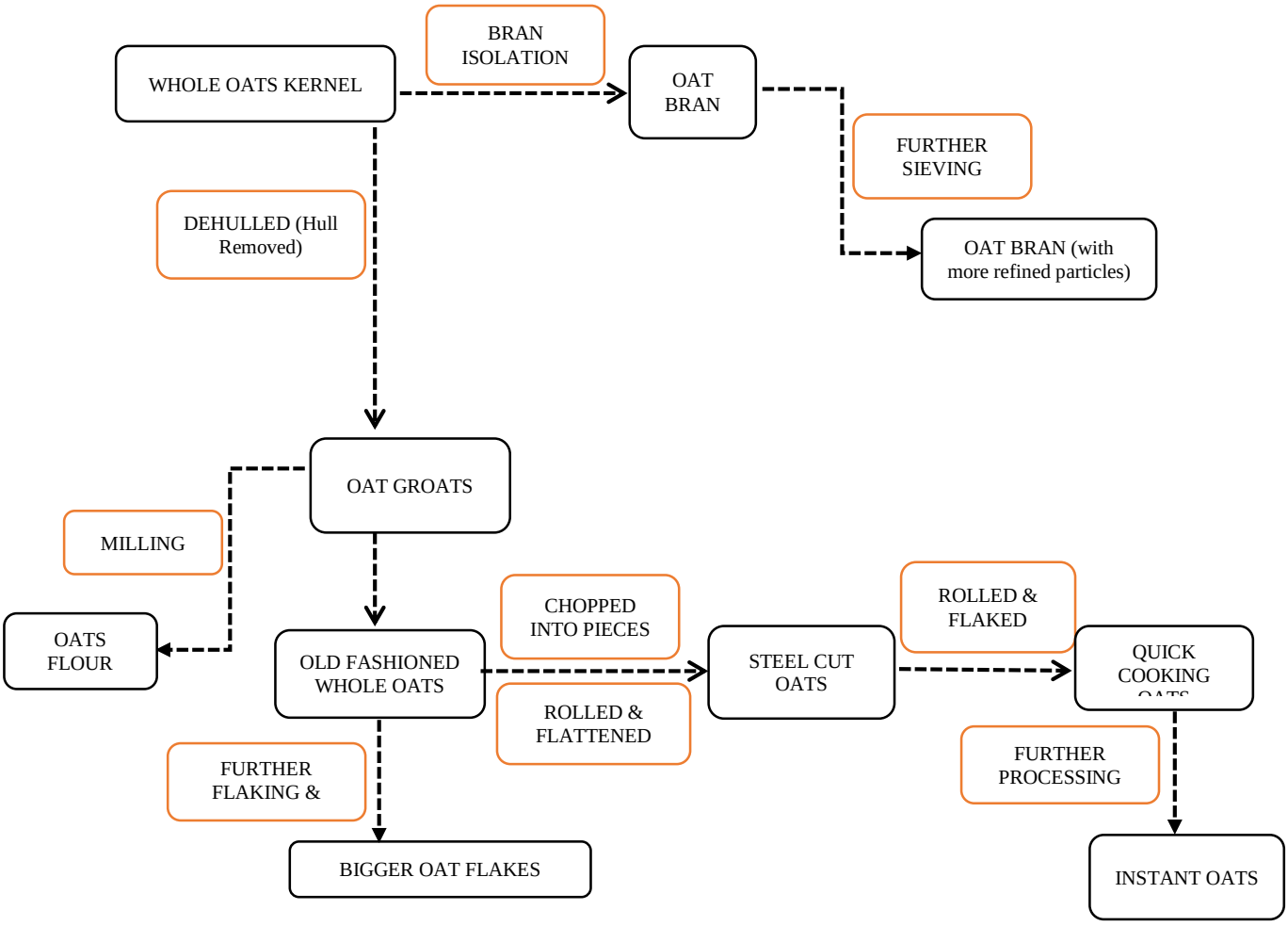

Fig 1: Processing of Oats & Oats

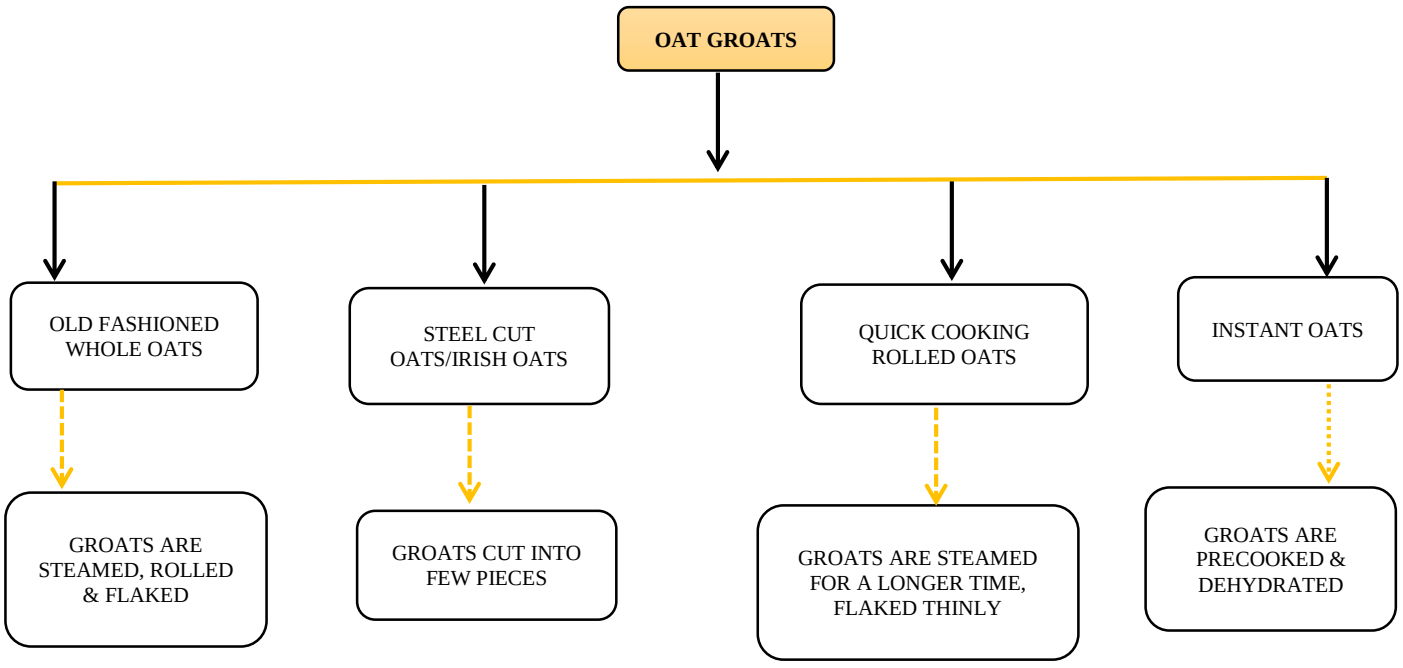

Fig 2: Commercial End Products of Oats

Table 1: Differential Properties of Oats

Properties	Steel cut oats	Old fashioned whole oats	Quick cooking rolled oats	Instant oats
Description	Whole oat groats chopped into pieces	Whole oat groats are steamed, rolled & flaked	Whole oat groats are steamed, rolled & flaked. The bigger flakes are chopped into smaller flakes.	Whole oat groats are precooked & flaked into thin pieces.
Flake size & appearance				
Texture	Hard & Grainy	Grainy & Creamy	Creamy & Soft	Soft & Powdery
Cooking time	10-15 minutes	7-10 minutes	5-7 minutes	Less than 2 minutes
Mouth feel	Crunchy & Chewy	Soft & Chewy	Pasty & Sticky	Dissolves in the mouth
Aroma	Nutty	Nutty	Nutty	Nutty

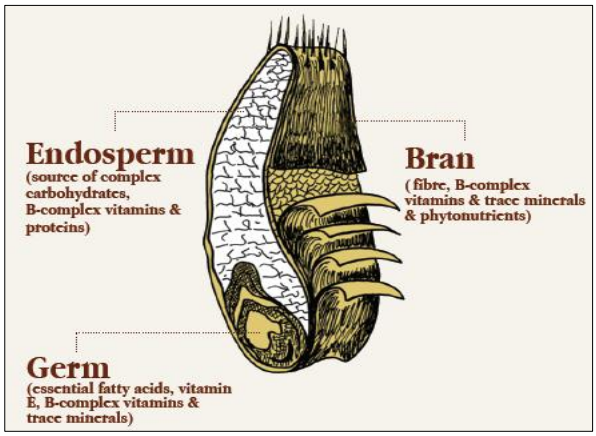

Fig 3: Structure of the Oat Grout

Nutritional profile of oats

Oat grout or whole grain (after removal of hull) contain all three parts (Fig. 3) of the grain – the germ, endosperm and bran, rich in all valuable nutrients (Table 2). In comparison to other cereals, oats are characterized with good amount of total protein, carbohydrate, crude fat, dietary fibre (non-starch), unique antioxidants and considerable vitamins and mineral content (Sangwan *et al.*, 2014). Total carbohydrate content (including cellulose and non-starch polysaccharides) may reach 75-80% of the dry matter. The main component of oat is starch and its content depends on the variety and growing conditions. The amylase content of oat starch ranges from 16-18% to 28.5–28.7% (Mirmoghtadaie *et al.* 2009).

Table 2: Nutritional composition of whole grain oat and oat bran

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

Source: (Usman *et al.*, 2010)

Oats contain a high percentage of protein and a balanced composition of amino acids (Table 3) which has a highly nutritive value in comparison to other cereals (Petkov *et al.* 2001).

Table 3: Amino acid composition of Oat Meal & Wheat (mg/per g N)

Amino Acids	Oat Meal (mg/per g N)	Wheat (mg/per g N)
Tryptophan	080	070
Threonine	200	180
Leucine	440	410
Isoleucine	270	220
Lysine	230	170
Methionine	100	090
Cystine	090	140
Phenylalanine	300	280
Tyrosine	210	180
Valine	330	280
Arginine	390	290
Histidine	110	130

Source: (Nutritive Value of Indian Foods, ICMR)

Phenol compounds present in oats and its by-products have a considerable antioxidant potential (Sobotka *et al.* 2012) [38]. Biologically the most important metabolically active proteins of oats are the enzymes. Oats are a good source of essential unsaturated fatty acids. The percentage varies depending upon the species. Triglycerides constitute the main component of lipids and phospholipids, glycolipids, sterols are also present in considerable quantities.

Health claims & benefits of oats

Oats are distinct among cereals due to their multifunctional characteristics and distinct nutritional profile. Oat and oat products have been proven to be helpful in the treatment of diabetes and cardiovascular disorders.

1. Oats help reduce cholesterol

Oats contain beta glucan soluble fibre that helps reduce cholesterol.
3g of soluble fibre daily from oats, in a diet low in saturated fat & cholesterol and accompanied by a healthy & active lifestyle helps reduce cholesterol (USFDA Guidelines).

In recent years, there has been interest in oats and oat products as bioactive high-value sources for human health in industries such as food, pharmaceutical, and cosmetic (Chu *et al.* 2013; Orozco-Mena *et al.* 2014) [8, 28]. Oats are rich in dietary fiber that comprises of a mixture of both soluble and insoluble fibers. One of the components of the soluble fiber found in oats is beta-glucans which are the major cholesterol reducing component of oats and are proven to be heart healthy (Villasmil *et al.* 2007; Butt *et al.* 2008) [35]. Different physiological effects of beta glucan (Fig. 4) are related to its viscosity, high transport of bile acids towards lower parts of the intestinal tract and high excretion of bile acids thereby lowering serum cholesterol levels, attenuation of post prandial plasma glucose levels. High values of cholesterol are a major risk factor for cardiovascular disease. Increasing dietary fiber has been recommended as a safe and practical approach for cholesterol reduction (beneficial adjunct to lipid lowering diets). Oats have been proven to have the ability to reduce the risk of heart disease (USFDA, 1997).

- The interactions of four separate processes may contribute to hypocholesterolemic effect of oat fibre. First, oat fibre can significantly increases fecal bile excretion and alters bile acid metabolism. Second, oat bran may alter lipoprotein metabolism, possibly by increasing hepatic LDL receptors. Oats tend to selectively lower LDL cholesterol to a greater extent than does HDL cholesterol. Third, oat bran is fermented in colon into short chain fatty acids like acetate, propionate, and butyrate and after absorption into portal vein, propionate may inhibit hepatic cholesterol synthesis. Fourth, decreases in insulin secretion associated with fiber such as oat bran could lead to reduction in cholesterol synthesis.
- Fiber from oats has been reported to be effective in reducing the risk of CHD because it favourably alters atherogenic fasting and postprandial serum lipids and other lipoprotein fractions independent of other dietary changes (Butt *et al.* 2008). Therefore, it is emphasised that the consumption of oats and oats products is extremely important to reduce the risk of cardiovascular disease (Singh *et al.* 2013)

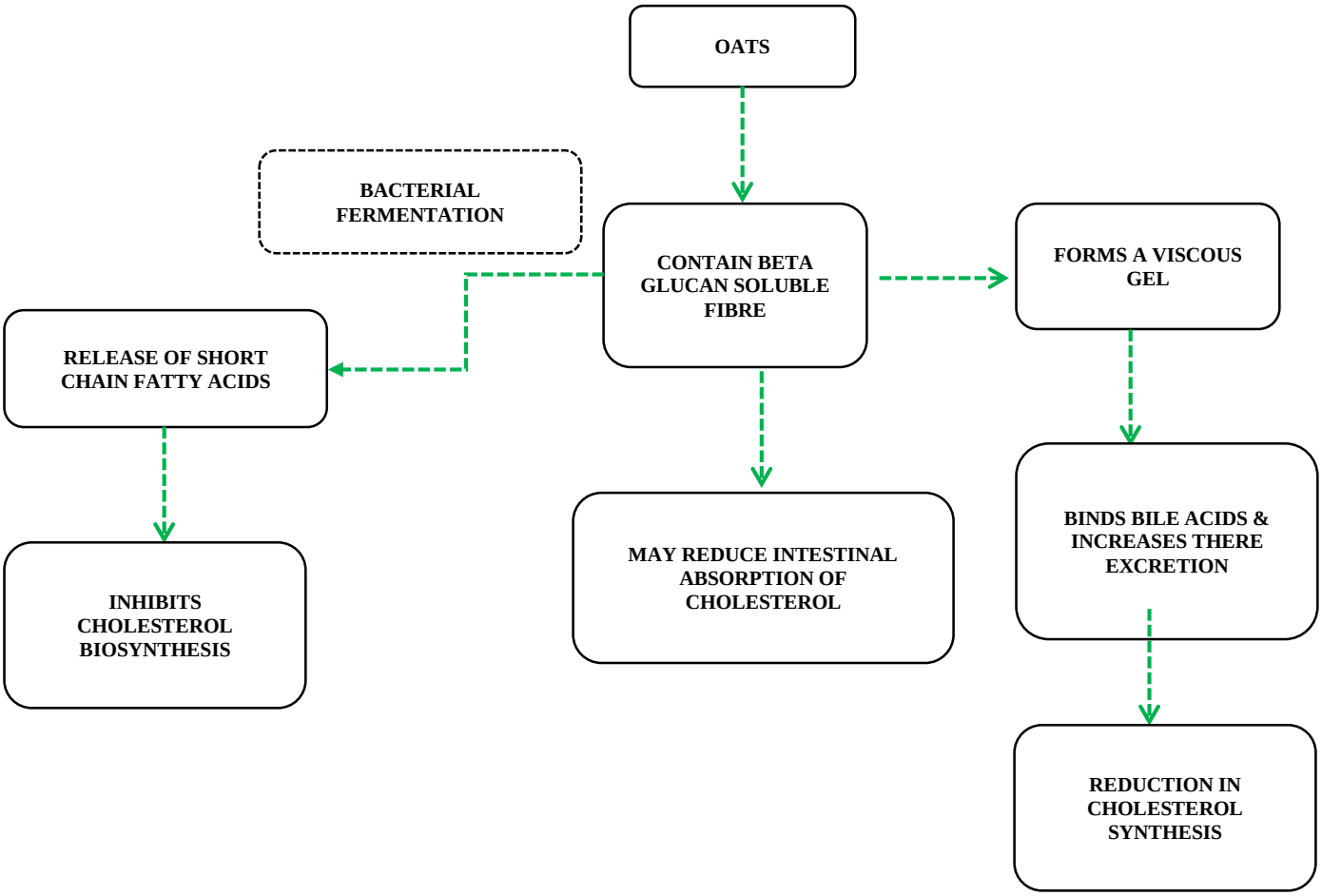

Fig 4: Mechanism of action

2. Oats help manage weight

Oats are rich source of dietary fibre. Diet rich in fibre may help maintain weight.
Epidemiological and clinical data suggest that fiber can aid in weight maintenance and/or the prevention of weight gain and subsequent obesity (>30% over ideal body weight).

Obesity is an independent risk factor for the development of coronary artery disease and also other risk factors such as dyslipidemia, high BP, and elevated blood glucose levels. Observational studies show that patients who lose weight show an improvement in coronary risk profile. Epidemiological & clinical data suggest that fiber can aid in weight maintenance and /or the prevention of weight gain and obesity. Fiber may impart a textural quality that increases chewing time (which is conducive for satiation).Viscous fibers (like that found in oats) have also been reported to prolong gastric emptying, small bowel transit time, and the digestion and absorption of carbohydrates and fat. These actions, which effectively alter glycemic response, have been shown to intensify satiety and aid in the control of energy intake. Meals enriched with beta-glucan elevate plasma levels of cholecystokinin (CCK), a hormone that mediates fat-induced satiety. Protein has also been found to be more satiating than isoenergetic amounts of carbohydrate or fat, and oats contains the highest protein content of all the common grains. Also, the amino acid composition of oats (low lysine to arginine ratio) has been shown to be hypocholestrolemic and may be cardioprotective (Katz, 2001).

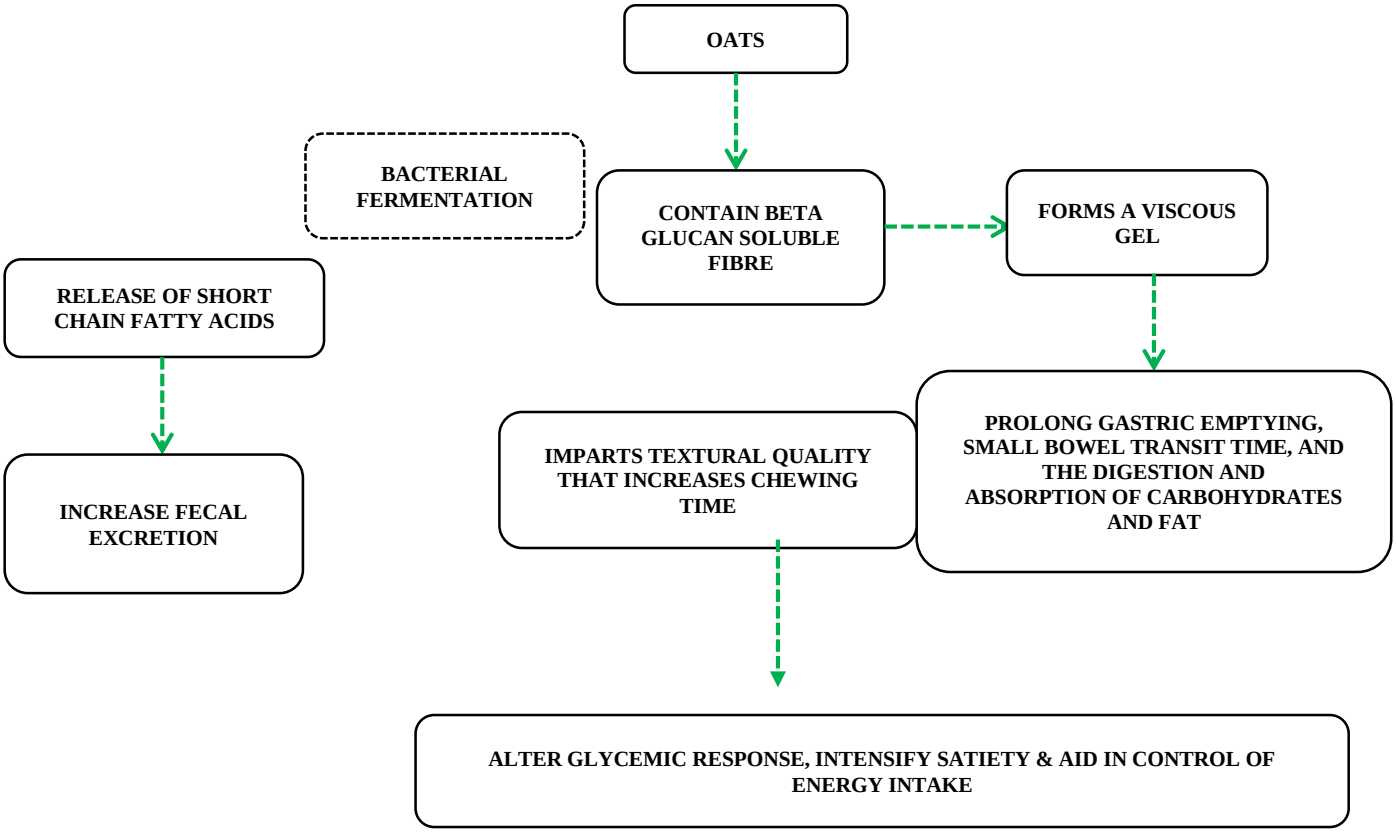

Fig 5: Mechanism of action

3. Oats may help reduce the risk of high blood pressure

Diets low in sodium may reduce the risk of high blood pressure, a disease associated with many factors. Individuals with high blood pressure should consult their physician (USFDA Guidelines).
Accumulating evidence from epidemiological, clinical, and animal studies suggests that fiber sources, including oats, can significantly aid in reducing blood pressure and/or prevent the onset of hypertension.

High blood pressure is defined as having a systolic BP >140mm of Hg or a diastolic BP >90mm of Hg. Due to the increasing internal pressure on the artery, hypertension contributes to endothelial injury and increases CHD risk by enhancing the infilteration of LDL particles. (Katz, 2001).

The DASH (Dietary Approaches to Stop Hypertension) study demonstrated that diet high in whole grains, fruits, vegetables and low fat dairy, and restricted in a fats lowers BP in hypertensive individuals. Dietary consumption of oats is consistent with the DASH recommendations, and may confer a benefit due to its fiber content. Oats as part of a healthy diet and active lifestyle can significantly aid in reducing BP and / or prevent the onset of hypertension. Further, soluble fibres in particular are more effective in lowering BP.

An epidemiological study conducted in various regions of southwest China demonstrated that individuals who reported eating more than 25g of oats/ day had lower systolic & diastolic BP values than individuals who reported eating less than 25g oats daily (associated with the soluble fiber content in oats). (Katz, 2001). The mechanism is described in Fig. 6.

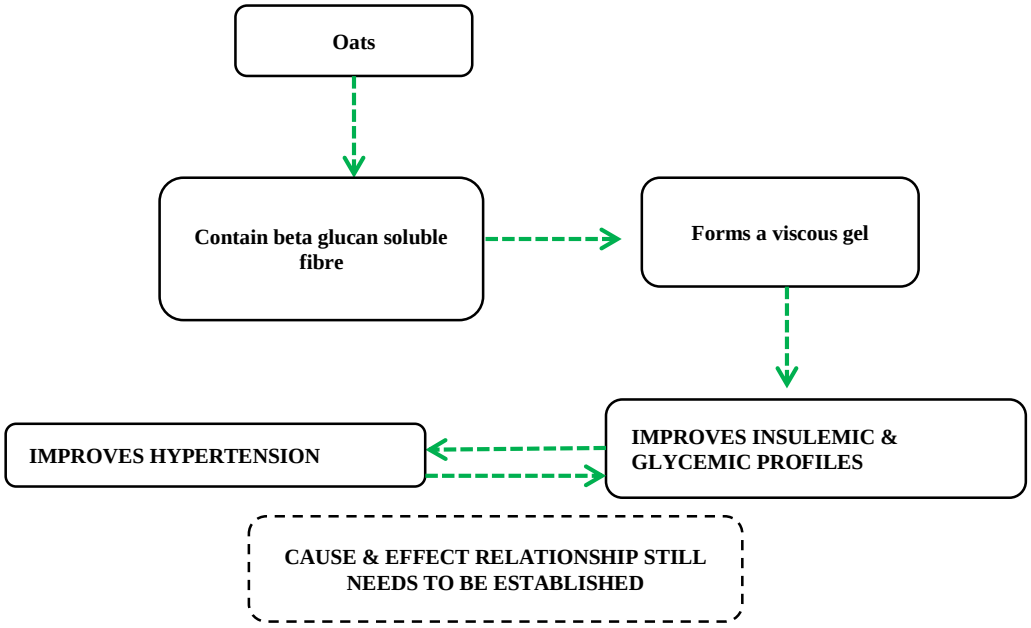

Fig 6: Mechanism of action

4. Oats improve post prandial glucose & insulin responses

Soluble fiber from oats, when incorporated into a low-glycemic diet, can improve postprandial glycemic and insulinemic responses.
Research suggests that oats, consumed as oat bran, oatmeal, or isolated beta-glucans, reduce both fasting and postprandial blood glucose and insulin levels.

Insulin resistance, the main component and causative factor of metabolic syndrome associated with type 2 diabetes is an essential target in the therapeutic approach of oat β- glucans. The dietary intake of total as well as soluble and insoluble fiber is inversely associated with insulin resistance, supporting evidence that a high intake of dietary fiber is associated with enhanced insulin sensitivity (Galisteo 2008; Ylonen *et al.* 2003). Oat β-glucans have been used in several clinical trials to reduce glucose level in blood. Oats act against diabetes and cause the lowering of blood glucose level through many ways (Fig.7).

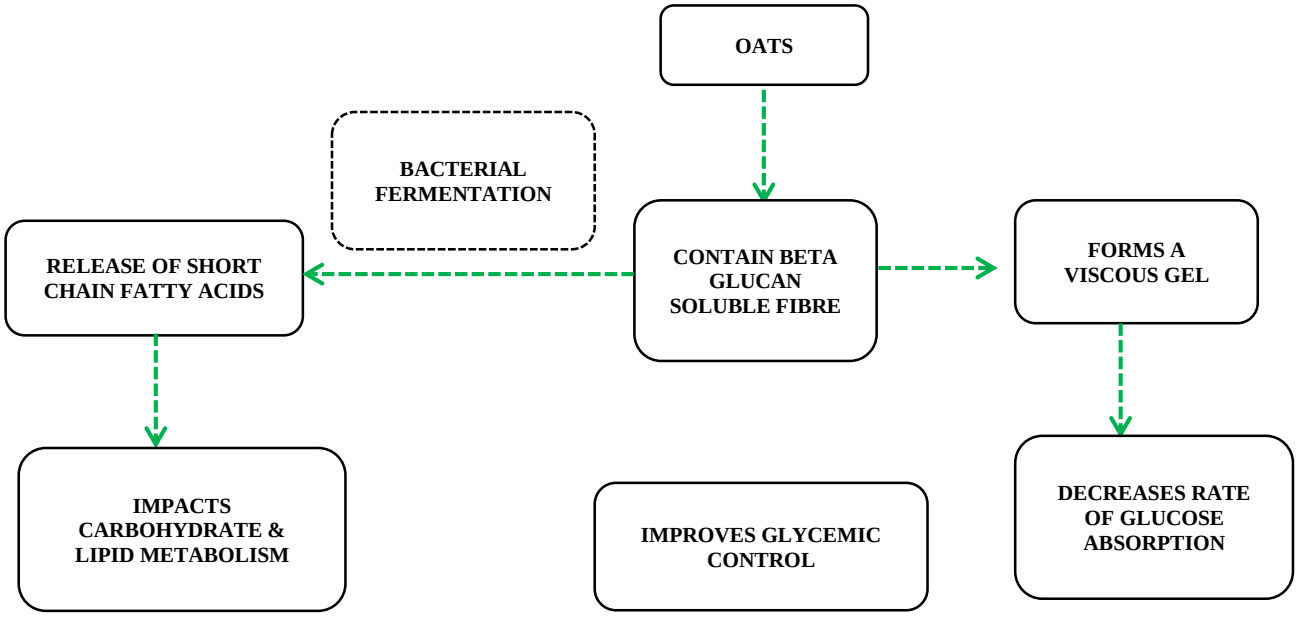

Fig 7: Mechanism of action

Beta glucans in oats owing to their property of being able to form a gel help manage blood glucose levels (particularly for cases of type II diabetes) (Butt *et al.* 2008.). Evidence from human studies reveal that the ingested gel forming beta glucans form a barrier to the digestion & absorption of nutrients (carbohydrates) resulting in a decreased rate of glucose absorption & attenuated blood glucose and insulin responses (Katz, 2001).) Tapola *et al.*, in their study "glycemic responses of oat bran products in type-2 diabetic patients," also concluded the same when they studied volunteers with type-2 diabetes fed on oat bran flour, oat bran crisp, and a glucose load providing 12.5 g glycemic carbohydrate (series 1) and 25 g glucose load alone, and 25 g glucose load with 30 g oat bran flour (series 2). In both series oat bran products rapidly lowered postprandial glucose concentrations than after the 12.5 g or 25 g glucose load during the 1st hour, but the glucose concentration was greater at 120 min after the oat bran products ingestion than after the glucose load. This decrease of glucose absorption will decrease insulin release and thereby attenuate pancreatic insulin response. Therefore, oat beta glucan has a greater effect at lowering peak glucose absorption concurrently with an attentuated insulin respone, which has a high significance in control and prevention of diabetes (Hooda *et al.*, 2010) [18, 20].

5. Oats reduce the risk of cancer

Oat has been recognised as healthy, due to its antioxidants, such as vitamin E and many kinds of phenolic compounds, which have been proved to have strong antioxidant activities *In vitro* and in vivo (Cai *et al.* 2011). Oat phenolics may serve as potent antioxidants by scavenging reactive oxygen and nitrogen species and/or by chelating transition minerals (Chen *et al.* 2004).

Recent research by Hong *et al.* have advanced the concept that orally administrered beta-glucan will exert an adjuvant effect when combined with exogenously administered antitumor antibodies that activate the components, and demonstrated that this mechanism of action is effective against a broad range of cancers when used in combination with specific monoclonal antibodies that activate or cause the complement to be bound to the tumor. The complement enables these primed neutrophils to find and bind to the tumor, which facilitates killing. Innate immune cells are the body's 1st line of defence and circulate throughout the body engaging in an immune response against "foreign" challenges (bacteria, fungi, parasites). Typically, neutrophils are not involved in the destruction of cancerous tissue because these immune cells view cancer as "self" rather than foreign or "nonself." Current cancer immunotherapies involve monoclonal antibodies and vaccines, which stimulate the acquired immune response, but do nothing to change the innate immune system's view of cancer as "self." As a result, the monoclonal antibodies alone do not engage or initiate the potential killing ability of the innate immune system, which is our primary mechanism of defence against bacteria and yeast (fungal) infections. Recently, orally-delivered β-glucan was found to significantly increase proliferation and activation of monocytes in peripheral blood of patients with advanced breast cancer (Demir *et al.*, 2007).

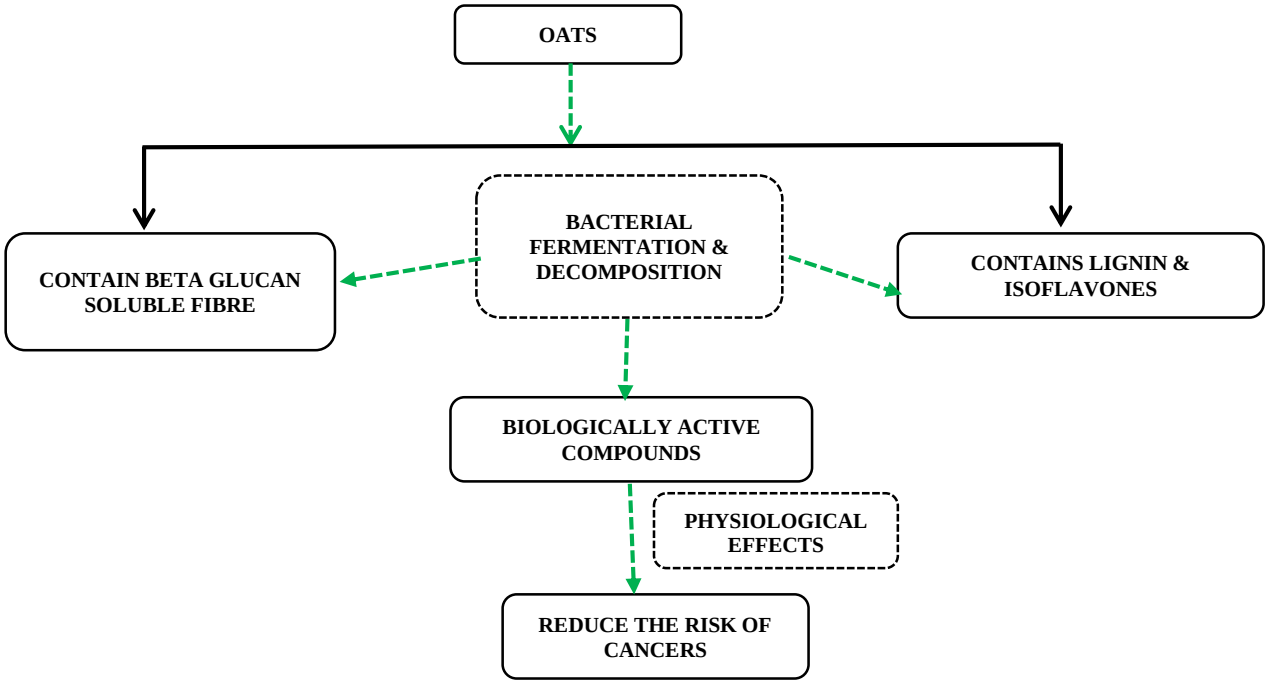

Fig 8: Mechanism of action

Mode of Action

In the large intestine beta glucan (Fig.8) is completely decomposed by bacterial enzymes and acts as a substrate for fermentations similar to other sources of soluble fibers. One of the most important physiological effects of these fermentations are probably the reduction of risk of intestinal and other cancers. A special advantage of oat fiber is its lignin and isoflavone content (phytoestrogens) these phytoestrogens (Lignin and Isoflavone) are converted by intestinal bacteria to biologically active substances. Over a long term period, these can reduce the risk of breast cancer, prostate and colon cancers (Perry & Young, 2016). Further research studies are required to validate & substantiate this claim.

6. Healthy gut & microflora: Effects on bowel function

Increased intake of dietary fiber is often useful in the prevention & management of constipation. Oats contain 55% (approx.) Beta glucan which is water soluble fibre and 45% (approx.) of water insoluble fibre. Soluble fiber has high swelling and water-binding ability and acts as a substrate of colonic fermentations. Due to poor absorbability insoluble fibre improves faecal bulk, laxation and ameliorate constipation (Bell et al. 2009). This reduces transit time and helps in treating constipation.

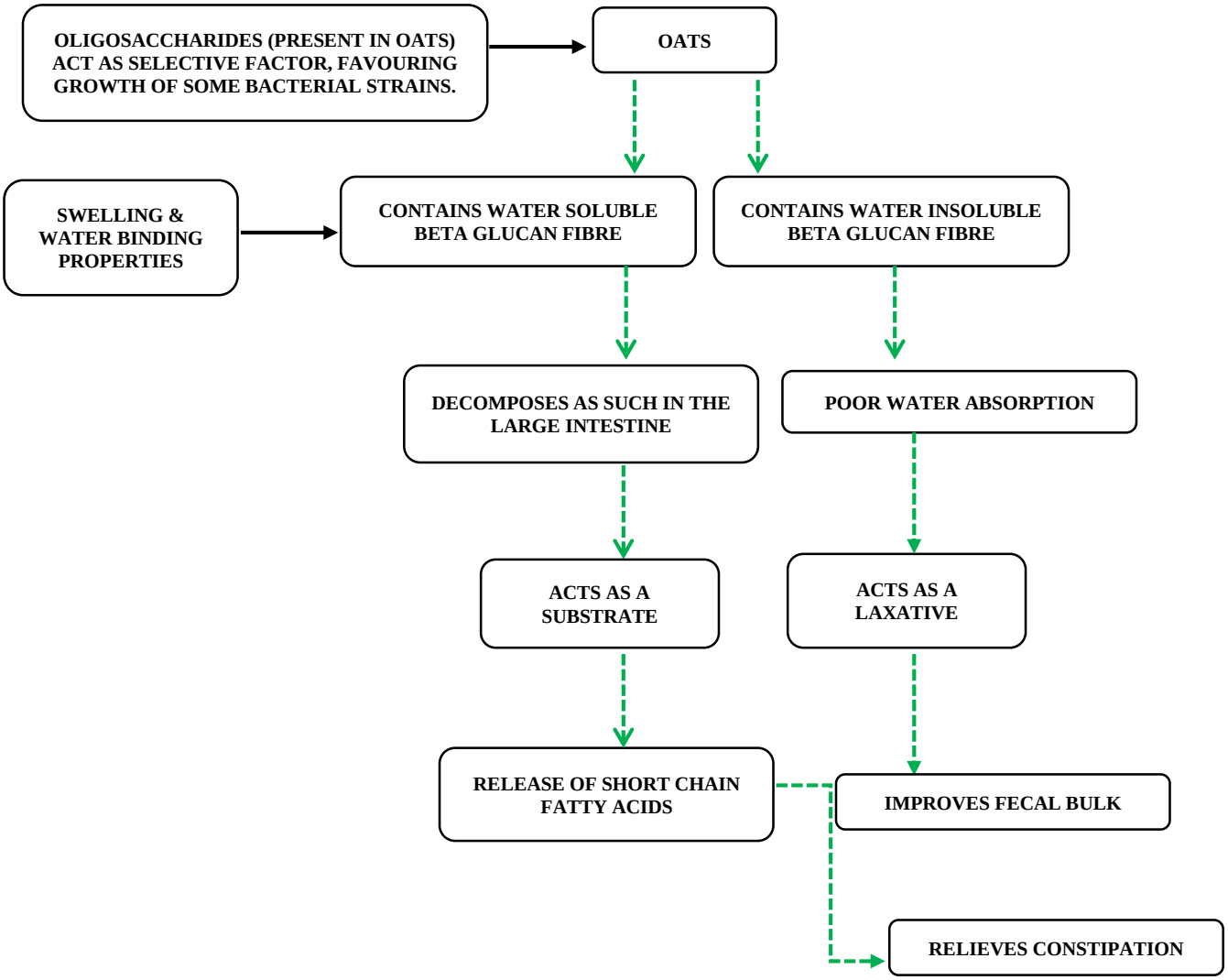

Fig 9: Mechanism of action

Oat *β*-glucan (Fig.9) behaves as a prebiotic: a nondigestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one strain or a limited number of bacterial strains in the colon and thus improves host health (Gibson and Roberfroid 1995). In small intestine of humans, beta-glucan remains intact, since no mammalian enzymes are able to hydrolyze it. Beta- glucan as such decomposes in the large intestine, the increase in dry weight is caused mainly by an increase in microbial cells. The microbial cell material also retains water which increases the water content of the stool & relieves constipation. In the large intestine *β*-glucan behaves as a substrate, favouring production of SCFAs. Its oligosaccharides have been demonstrated to act as selective factor, favouring growth of some bacterial strains. The favorable effect on colon function is based partly on the enhanced production of microbial mass with good water retention properties, partly by the bulking effect of insoluble components of the fiber (Malkki & Vritanen., 2001; Perry & Young, 2016).

7. Store house of antioxidants: Aventhramides

Oats also provide a unique blend of antioxidants which include wax alcohol and acid esters; avenanthramides and oat saponins. Aventhramides (AVAs) are important phenolic compounds found in oats. They are constitutively expressed in the kernels, appearing in almost all milling fractions, but occur in the highest concentration in the bran and outer layers of the kernel (Meydani 2009).

The antioxidant activity of AVAs has been found to be 10–30 times higher than those of the typical cereal components ferulic acid, gentisic acid, phydroxybenzoic acid, protocatechuic acid, syringic acid, vanillic acid, and vanillin (Verardo *et al.* 2011; Orozco-Mena *et al.* 2014; Yang *et al.* 2014) [28, 46]. These oat extracts have been shown to inhibit the formation of reactive oxygen species *in vitro*, which oxidize and promote the atherogenicity of LDL- cholesterol. Oat phenolics have been

shown to increase the resistance of human LDL to oxidation in a dose dependant fashion (can synergistically interact with Vit. C in diet). This further enhances heart healthy benefits of oats (Meydani 2009).

5. Oats are gluten free: The perfect cereal replacement for celiac patients

The common oat, (*Avena Sativa)*, has a multitude of nutrition benefits. Oats are also proven to be efficacious in the dietary management of celiac disease (Butt et al, 2008). Oats are officially concluded as gluten free by European commission regulation (EC) No. 41/2009 and thus found to be suitable for the celiac patients (Rasane *et al.*, 2015) [33]. Oats can help improve the nutritional value of the gluten free diet. The safety of oats in individuals with celiac disease has been extensively investigated. Clinical evidence confirms that consumption of pure & non-contaminated oats is safe upto 50-70g/d (adults); & 20-25g/d (children). Protein found in oats avenin does not trigger autoimmune responses in people with celiac disease {allergic to gliadin & gluten proteins in wheat/ other cereals} (Butt *et al.* 2008). Hence, gluten free products such as pasta, biscuit and snacks have been developed for celiac patients from oats (Ballabio *et al.*, 2011) [4].

Future research oppertunities

Oat compounds provide various opportunities for incorporating oats in functional food products. There is a great need to determine the bioavailability of antioxidants from oat and to determine its impact on human health. From this article it can be concluded that β – glucan (along with aventhramides) is the main active ingredient responsible for the all physiological & nutritional benefits of oats. Oats, being a convenience cereal, requires more scientific attention to substantiate and validate its nutraceutical status in geriatric as well as paediatric diets. Research and development is further needed to determine novel functional compounds in oat that can be incorporated in food products. It will be interesting to know how β – glucan could be used in the new product development that are used in our daily diets, the effect of various processing & packaging techniques on β- glucan and its interaction with other components of food matrix. Cardiovascular disorders, obesity & diabetes are being envisaged as a global concern. Therefore, products derived out of oats need to be developed to satisfy the growing nutritional & health needs.

List of Abbreviations

Approx.	- Approximately
AVAs	- Aventhramides
BP	- Blood Pressure
CCK	- Cholecystokinin
CHD	- Coronary Heart Disease
DASH	- Dietary Approaches to Stop Hypertension
HDL	- High Density Lipoprotein
LDL	- Low Density Lipoprotein
OβG	- Oat Beta Glucan
USFDA	- U.S Federal Food and Drug Administration

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