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WHOLEGRAIN OATS: ROLE IN *PREVENTIVE LIFESTYLE* FOR MANAGING NONCOMMUNICABLE DISEASES IN INDIA

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ABSTRACT

The burgeoning prevalence of noncommunicable diseases across the globe is a cause of concern due to increased rates of deaths, both in developed and developing economies. Cardiovascular diseases are the leading cause of death by noncommunicable diseases and WHO states that 75% of these deaths occur in developing economies. Consumption of suboptimal diets consisting of lesser whole grains, fibre and good-quality proteins is one of the primary modifiable risk factors for metabolic syndrome developing into noncommunicable diseases. Indian diets are predominant in cereals leading to their daily intakes higher than the recommended amounts. Hence, it is imperative to choose the cereals wisely to provide more complex carbohydrates along with essential nutrients like fibre, protein & micronutrients. WHO states that both, the quality and the quantity of nutrients are equally important in a balanced diet to maintain good health. Oat is among the ancient food grains grown and consumed worldwide. It has gained popularity owing to its nutritional composition due to unique fibre, protein and bioactive compounds leading to multifunctional benefits. Beta-glucan is the soluble dietary fibre found in oat grains with proven cholesterol-lowering and antidiabetic effects. Oat proteins are of higher quality than most other cereals. The presence of several bioactive compounds such as phenolic acids, tocopherols, sterols, avenacosides, and especially, avenanthramides increases the nutritional credibility of the grain. The interplay of these nutrients in oat grains, to regulate the gut microflora for immunomodulation, weight management and cardiovascular diseases is also well established. This review aims to focus on oat grains' composition and the contribution of oat-based products in managing noncommunicable diseases to maintain normal health.

Keywords: non communicable diseases, beta glucan, obesity, oats, whole grain

INTRODUCTION

Health Crisis in India

There has been an alarming rise of chronic non communicable diseases (NCDs) in India since the past few decades and NCDs (that include cardiovascular diseases, chronic respiratory disease, cancer and diabetes) contribute to around 5.87 million (60%) of all deaths annually. The *triple burden of malnutrition* refers to a complex & multifaceted nutrition challenge that many developing countries in the world are facing, including India. It refers to the coexistence of undernutrition (stunting), micronutrient deficiencies (hidden hunger) & overnutrition (overweight and obesity). The alarming rise in NCDs can be attributed to suboptimal dietary selections characterized by an absence of essential nutrients, as well as heightened consumption of nutritionally deficient foods, coupled with a notable deficit in physical activity (Nethan et al, 2017; Miller et al, 2020 & WHO, 2023).

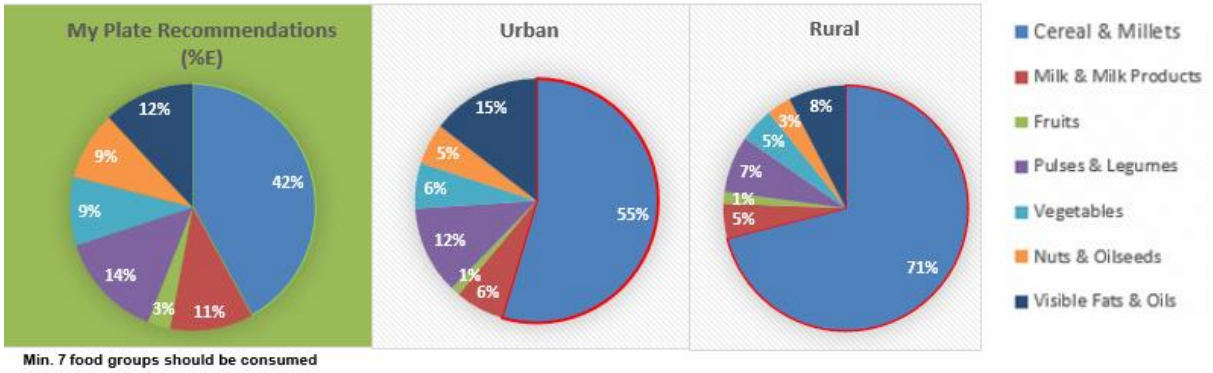
A large proportion of this *overnutrition burden* is shared by developing countries, including India, which contribute to 75% of the global deaths due to NCDs (WHO 2023). In India, 53% of total deaths are due to NCDs. Research indicates that suboptimal diets significantly impact mortality and morbidity due to NCDs, worldwide. Current Indian diets are limited in essential nutrients including fibre, protein, good fats (MUFA and PUFAs), vitamins, and minerals, and higher in simple sugars (free sugars), saturated fats, and trans-fats. Certain risk factors for NCDs are modifiable, prompting individuals to adopt healthier lifestyles. Post Covid, consumers are focussing more on physical and mental health. The onset age for many NCDs among the Indians has decreased now a decade or two versus earlier and has been a decade earlier than other populations (Prabhakaran 2016; Anjana et al. 2023).

Multiple epidemiological studies have established an inverse relation between wholegrains (WG) consumption & incidence of CVDs. WG, besides being rich in dietary fibre (both soluble and insoluble), provide an abundance of nutrients such as minerals, vitamins, and phytochemicals, enriching the quality of diets. (Yang et al 2022; Hu et al 2023).

Dietary Patterns of Indians

Indians largely consume cereals in their daily diets. According to the Indian Council of Medical Research (ICMR) recommendation (ICMR-RDA, 2020), Indians should consume about 42% (260g) of total food from cereals, while the actual consumption ranges from 50-70% (300-500g). ICMR (2020) also recommends 50% of grains as WG and 20-30% as millets including ragi, jowar and bajra. 40-50% of energy should come from carbohydrates, mainly complex carbohydrates providing soluble and insoluble fibre, 10-12% from good quality proteins and 15-30% from fats. Indians consume a large amount of fats and saturated fats, sugars and sodium from in-house cooked foods and very little of fruits and vegetables, milk and milk products and WG. These suboptimal levels of beneficial components along with the genetic makeup of Indians predispose them to metabolic syndrome which is manifested as NCDs. Genetically, Indians are called "*thin fat babies*" due to their increased tendency to store fats at subcutaneous and abdominal (visceral) sources. Increased abdominal fat is associated with increased incidence of metabolic syndrome. Micronutrient deficiencies in Indians, especially among the younger population, also couple up as a major risk factor for the increased prevalence of metabolic syndrome succeeding to NCDs (NFHS 2019; Mozaffarian 2023).

Fig. 1 Comparison of food group intakes in Indians versus the recommendations



In this review, we aim to explore the benefits of WG oats due to their differentiated nutritional profile *w.r.t.* fibre, protein, and bioactive compounds. We also delve into the established results due to the intervention oats-based products in the management of NCDs like CVDs, hyperglycaemia and hypertension.

What is a Whole Grain

The commencing point of every grain (cereal and millet) is as a "*whole grain*". As per the Whole Grain Council (WGC, 2024), a grain is considered a WG when all its parts – the *bran, endosperm* and *germ* are present in natural proportions delivering the naturally occurring nutrients content, as when the grain is growing in the field. Foods made of WG should consist of all these three parts, even after being processed (using techniques like cracking, extrusion, crushing rolling, *etc*). WG foods should provide the nutritional benefits of all three parts of the WG. WG mainly include grains of amaranth, barley buckwheat, corn, oats, and millets like sorghum, and pearl millet. WG contain bran, germ & endosperm in contrast to refined grains which only have the endosperm component. Removal of germ & bran in the milling process causes a loss of many essential nutrients such as dietary fibre, b-complex vitamins & minerals. (Aune et al, 2016).

WG recommendations across the globe

National and international health authorities including the British Nutrition Foundation, Dietary Guidelines for Americans, WHO, FAO, Singapore Dietary Guidelines, Canada's Food Guide, DTU (National Food Institute, Denmark), German Nutrition Society, French National Nutrition & Health Program, ICMR and many others, recommend the consumption of WG (Whole Grains Council).

Oats: The Wholegrain

Oats are ancient grains grown earlier in the Mediterranean region. It is the sixth major grown cereal across the globe after wheat, maize, rice, barley and sorghum. It is majorly grown in the USA, Australia, Canada, Germany, and Poland. In India, Oats are grown in Jammu and Kashmir, UP Bihar, Orissa, and Himachal Pradesh. Oats grow well in cold and temperate climates between 15-25ºC and are unaffected by frosts and snows (ICAR 2023).

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Table 1. Global Whole Grains recommendations.

S. No.	Nutrition Authority	WG recommendations
1	Dietary Guidelines for Americans (2015-2020) [US]	Daily intake of WG is to be at least half of total grain consumption.
2	British Nutrition Foundation 2022 [UK] – Eatwell Guide	Choose WG over refined grains. E.g.- Wholewheat varieties of pasta, noodles and couscous, Grains such as brown rice, bulgur wheat, barley, rye, quinoa, corn, oats and freekeh
3	Health Promotion Board [Singapore]	Consume two - three servings of WG foods (or 50g of WG) every day
4	Food-based dietary guidelines for Scandinavian countries [Norway, Sweden, and Denmark]	Intake of minimum 75 g WG per 2,388 kcal/day
5	The Chinese Nutrition Society, 2016	The daily number of cereals and potatoes consumed for body energy production should be 250–400 g, including 50–150 g of WG & mixed beans and 50-100g of potatoes
6	The French National Nutrition and Health Program's Dietary Guidelines.	Include WG cereals as a part of starch foods, preferably at each meal.
7	Indian Council of Medical Research (ICMR-RDA), India	50% of total cereal recommendations should be from WG

Table 2. Standards of Whole Grains on Products.

S. No.	Country	Definition
1	Brazil (April 2021); ANVISA	A WG food must meet the following two requirements: 1) At least 30% of the product's ingredients (by weight) must be WG, and 2) the product must contain more WG ingredients (by weight) than refined grain ingredients.
2	EU (2017)	A WG food is one for which the product is made with at least 30% WG ingredients on a dry-weight basis and more WG ingredients than refined grain ingredients.
3	USA (2016); (USDA/CACFP)	At least one serving of grains per day must meet the Food and Nutrition Services definition of WG rich (established in 2012).
4	USA (2013) (AACC International)	Characterization of a *WG Product*- A WG food product must contain 8 grams or more of WG per 30 grams of product.
5	USA (2012) USDA FNS Schools	Food must be at least 1 of the 3 a. 8g WG/serving b. Meets FDA WG health claim (51%WG by weight) c. WG as the first ingredient or first grain by weight for non-mixed dishes (breads/cereals); first grain ingredient for mixed dishes (pizzas, biscuits, *etc*.) Essentially, at least 50% of grains should be WG
6	Netherlands (NBC; Dutch Bakery Centre)	Breads can be legally called WG if they are 100%WG. Terms like 20%, 30%, 80% WG are not allowed.
7	Canada (2007) Whole Grain Council; Whole Grain Stamp	Min 8%WG per serving (Basic WG stamp) Min 16% WG and all ingredients are WG (100%WG stamp)

As per the World Whole Grains Council, it is difficult to remove oat components in milling, as germ & bran are tightly bound. This implies that consumers, regardless of the specific type of oats chosen, can be assured of receiving WG with all three components (germ, bran, and endosperm) preserved in the same proportion as found in the original grain.

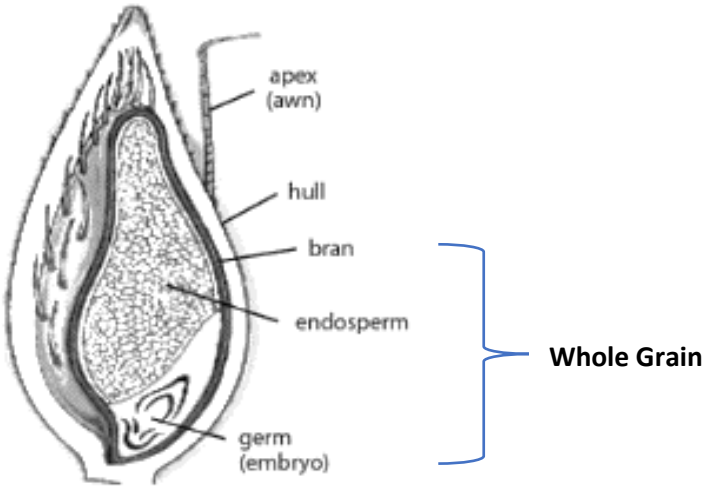

Fig. 2 Structure of Oat grain

Oats Nutrition

Cereal grains play a crucial role as a global dietary energy source, accounting for 50% of the total energy, with the proportion being higher in developing countries. The most widely consumed cereals worldwide, in descending order, are rice, wheat, and corn. Oats, barley, rye & millets consumption numbers are on the rise.

Table 3. Macronutrient profile of major cereal grains (per 100g)

S. No.	Cereal grain	Energy (kcal)	Carbohydrates (g)	Dietary fibre (g)	Soluble fibre (g)	Insoluble fibre (g)	Protein (g)	Fat (g)
1	**Rice**	356	78.2	2.8	0.8	2	7.9	0.5
2	**Wheat**	322	64.7	11.2	1.6	9.6	10.6	1.5
3	**Corn**	334	65	12.2	0.9	11.3	8.8	3.8
4	**Oats**	375	67.5	10	5	5	12.5	6.2
5	**Barley**	316	61.3	15.6	5.7	9.9	10.9	1.3

Unique Components of Oats:

1. Oat Starch

In the oat grain, starch (approximately 60-65%) is in the endosperm, surrounded by the β-glucan and protein in the bran layer. As compared to other cereals, starch in oats is different due to the strong association of starch and protein and the presence of β-glucan. Also, oats contain higher amylose than other cereals, ranging from approximately 25-29%, depending on the area of cultivation & genotype.

Oat starch has lower digestibility as it has a higher ***amylose: amylopectin ratio*** than most cereals. A higher content of resistant starch (25-29%) versus other cereals, also contributes to a controlled spike in blood glucose after oats consumption, depending on the cooking methods used. Extensive cooking methods involving moist heat like pressure cooking, prolonged boiling, steaming, *etc*. may cause complete disintegration of the starch causing pre gelatinisation, causing an increase in glycaemic index (GI). GI of a food is its relative potential to increase blood glucose levels as compared to a reference food (white bread). Cooking methods such as roasting, parboiling, and partial cooking have a lower impact on GI. Particle size of Oats grain has a major impact on the glycaemic response. Minimally processed steel-cut oats (groats with bigger particle size) have lower GI as compared to instant oats (with fine particle size) and lower insulinemic & glycaemic responses were noted after consuming less processed Oats (Wolever et al. 2019).

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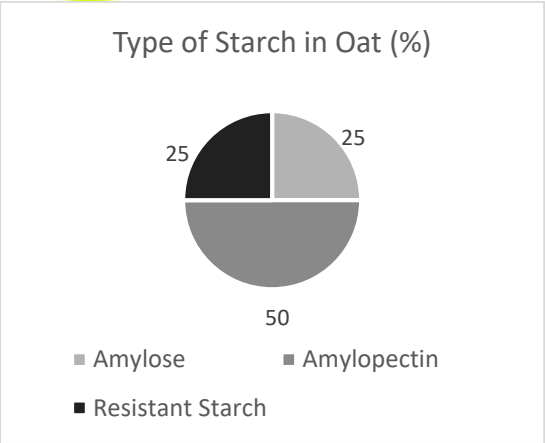

Figure 3. Starch composition of Oats

Factors responsible for the slow digestion of starch in oats are-

- Fewer short branch chains (DP < 13) and less branching of amylopectin, causing low enzyme accessibility.
- Resistant starch that acts as a functional fibre accounting for 29% in oats, is higher than most other cereals.
- The presence of slow digesting resistant starch RS2 that is compact, reducing the accessibility to enzymes.
- High lipids in oats coupled with high resistant starch contribute to a slower release of glucose as the amylose lipid complex is resistant to enzymatic digestion.
- GI is also modified by the gut microbiota produced by fermentation of resistant starch in the colon.

2. Oats Fibre (β-glucan)

Oats grain contains an important and valuable soluble fibre called beta-glucan (β-glucan), ranging from 3-8% of the grain. β-glucan, especially (1-3) (1-4)-β-D-glucans is proven for therapeutic multidirectional benefits in NCDs. Oats contain the highest soluble to insoluble fibre ratio among cereals (fig. 3). Soluble fibre exhibits greater efficacy in improving glycaemic response as well as mitigating the risk of CVDs as compared to insoluble fibre. (Mao et al, 2021) Oats β-glucan structure is made of long unbranched chains of β-D-glucose linked by β-1,3-glycosidic (30%) and β-1,4-glycosidic (70%) bonds. The β-glucan structure depends on the ratio of DP3 & DP4 fractions of glycosidic bonds, which determines physical properties such as gel state and solubility.

Molecular weight also influences the properties of β-glucan greatly. β-glucan from oats has the highest molecular weight among cereal plants, ranging from 65 to 3100 × 103 Da. Oats β-glucan absorbs large amounts of water, forming gums with considerable viscosity.

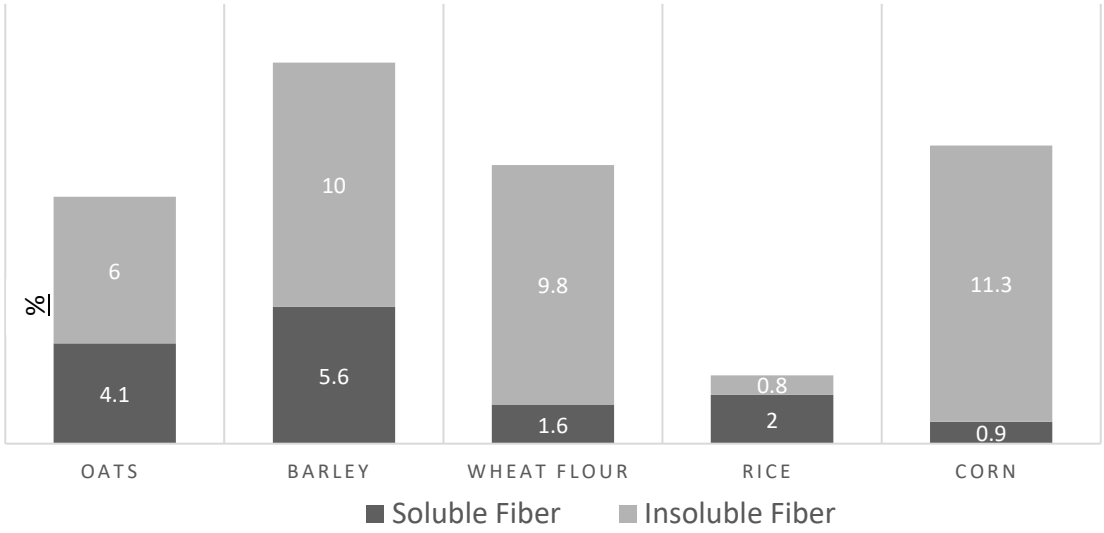

Figure. 4 Distribution of soluble & insoluble fibre in cereals.

This viscosity causing property of β -glucan is responsible for lowering the cholesterol & improving glycaemic response when taken in appropriate doses. Regular consumption of β-glucan, 1g/serve or 3g/day, is known to reduce LDL-C (low density lipoprotein cholesterol) in humans (Alemayehu et al 2023).

Barley also contains β-glucan similar to oats, however, the content of (1,3) -(1,4)-D-glucan is higher in oats endosperm than barley, which means the ratio of soluble β-glucan to total β-glucan is higher in oats as compared to barley (Alemayehu et al 2023; Leszczynska et al 2023).

Molecular weight (Mw) of β-glucan highly affects the clinical benefits

European Food Safety Authority (EFSA) approved a health claim for lowering glucose response when at least 4 g of β-glucans, from oats or barley, per 30 g of available carbohydrates are consumed in a meal. The mechanism of action for the effect being the viscosity they generate, oats β-glucans will result in a slower rate of gastric emptying, which, in turn, delays the delivery of the chyme to the intestine. High Mw β-glucans are capable of generating a viscous solution, as compared to low Mw β-glucans.

Table 4. Amino Acid content of commonly consumed cereals.

S. No.	Commonly consumed Cereals	DIAAS
1	Oats	0.57
2	Wheat	0.4
3	Corn	0.36
4	Rice	0.47
5	Barley	0.55

A broader and flattened peak blood glucose rise (PBGR) curve was observed with the solution prepared with 580 kDa β-glucan as compared to the solution of Glucose prepared with 145KDaβ-glucan. (Henrion et al. 2019; Regand et al. 2011).

β-glucans of 2133 kDa were also significantly more effective at reducing the glucose incremental area under the curve (iAUC) and the PBGR than other formulations with low Mw β-glucan ranging from 32 kDa to 435 kDa. (Regand et al 2009).

3. Oats proteins

Protein quality is essentially the presence of essential amino acids in the food along with the digestibility. While some foods may offer high protein content, their quality can be compromised if they lack these essential amino acids. Plant proteins are often incomplete in this regard when compared with animal proteins.

Dehusked oats contain significantly more essential amino acids than husked oats (48.6g/kg vs 38.6g/kg), making them a superior protein source, highlighting the importance of considering amino acid quality in your diet. Most of the oats that are commercially sold for human consumption are dehusked. The protein content in oats ranges from 12.4-24.5% (Sterna et al, 2016).

Multiple data show that consuming 100 g of oatmeal can cover the daily requirement for seven essential amino acids, with only sulphur amino acids and lysine being deficient (Danuta et al. 2023; Rasane et al. 2015).

Distinctive protein quality of Oats: Unlike other cereals, where prolamin is the major storage protein, oats are an exceptional case, where **globulins form the major storage protein**.

Table 5: DIAAS scores of commonly consumed cereals

	Wheat	Maize	Rice	Oats	Barley	Jowar	Bajra	Ragi
Total protein (g/100g)	10.6	8.8	7.9	10.1	10.9	10	11	7.2
Total Essential Amino acids (g/100g)	3.7	3.2	2.7	4.1	3.0	3.6	4.7	1.7
Total Non essential amino acids (g/100g)	7.7	5.3	4.7	7.4	6.9	6.4	6.3	5.5

Prolamins form 10%-20% of the total protein in oats, compared to 40%-50% of the total protein in wheat, prolamins have lower lysine (which is a major rate limiting AA) than globulins, hence oats protein possesses a higher biological value than other cereals. *Digestible Indispensable Amino Acid Score* (DIAAS)

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is a protein quality method proposed by the Food and Agriculture Organization (FAO), which ranks a food product based on amino acid digestibility & absorption of the food to meet human amino acid requirements. Oats have the highest DIAAS score among commonly consumed cereals, which means it is one of the most effective protein sources to fulfil human requirements among cereals.

Oats Lipids

Oats are a good source of fats. Fats constitute about 5-9% of the grain, which is the highest among all cereals. Endosperm contains most of the fats. The fatty acid composition of oats has a favourable fatty acid composition as compared to other cereals. Oat lipids comprise 75-80% unsaturated fatty acids, with higher amounts of monounsaturated fatty acids (MUFA); and polyunsaturated fatty acids (PUFAs) like linoleic acid (omega 6 fatty acid) & lesser amounts of saturated fats (Paudel et al, 2021). This fat composition abides the dietary recommendations by health authorities, including ICMR, for healthy living.

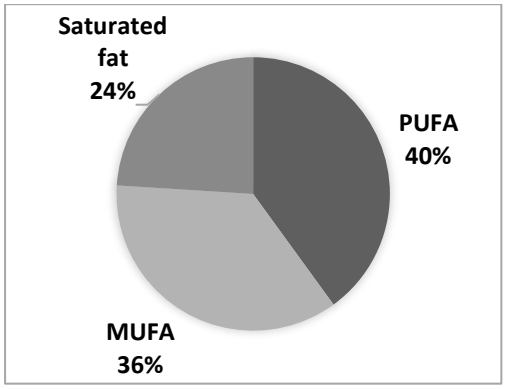

Fig 5. Fatty acid composition of oat lipids

4. Oats Polyphenols (Avenanthramides) & other Bio-actives

Oats contain significant amounts of phenolic compounds that scavenge free radicals & act as potent antioxidants. Oats exhibit greater antioxidant potential compared to wheat, and other cereals, mostly attributed to the presence of avenanthramides, phenolic compounds, vitamin E, and phytic acid. Additionally, oats grains contain flavonoids and sterols.

Avenanthramides (AVAs)

Whole oats are the only food source of AVAs, a unique group of polyphenols that can protect against heart disease. They may reduce inflammation in the arteries and regulate blood pressure.

The AVAs content of oats ranges from 3 to 289 mg/kg. There are more than 20 distinct forms of avenanthramides (AVAs) present in oats differing in the substituents of the acid rings, but the three major forms are A, B, and C. Among the three major AVAs in oats, AVA-C typically constitutes approximately one-third of the total AVAs concentration in oats grain and exhibits the highest antioxidant capacity. These compounds are found in relatively high concentrations in WG oats (up to 300 ppm or 0.03%) and in the outer regions of the oats kernel, such as bran and sub-aleurone layers.

The bioavailability of AVAs has been studied in humans. Consumption of oats enriched with 0.5-1g AVA resulted in increased plasma concentrations of AVA. The consumption of oats also elevated plasma Glutathione levels, indicating that AVAs in oats possess potent antioxidant capacity (Chen et al, 2007).

Chemical Structure: With respect to their chemical structures, AVAs represent amides of different *hydroxycinnamic acids* with *anthranilic acid*. All three types contain 5-hydroxyanthranilic acid while hydroxycinnamic acids involved are p-coumaric acid for AVA-A, ferulic acid for AVA-B, and caffeic acid for AVA-C (Boz H,2015).

Other Bioactives

Other than AVAs, oats contain varied bioactive compounds such as vitamin E (tocopherols), carotenoids, anthocyanins, lignans, phytic acid, phenolics and phytosterol. Phenolic compounds like AVAs are protocatechuic, syringic, vanillic, p hydroxybenzoic, gallic, p-coumaric, o-coumaric, and caffeic acids. These bioactives possess antioxidant & anti-inflammatory properties (Kim et al. 2021).

5. Oats Micronutrients

Micronutrients are vitamins and minerals that are required in small amounts, however, their role in the normal function of body systems is extremely critical.

Vitamins: B-complex vitamins are found in significant amounts in oats, which aid in energy metabolism and amino acid metabolism. 100g oats contain the highest thiamine (Vitamin B1) & Folate among commonly consumed cereals, that is, wheat, corn, and rice. Oats are not a good source of fat-soluble vitamins.

Table 6. Constituents of AVAs types.

Avenanthramide type	R1	R2	R3	Anthranilic acid	Cinnamic Acid
AVA-A	OH	H	OH	5-hydroxyanthranilic acid	p-coumaric acid
AVA-B	OH	OCH3	OH	5-hydroxyanthranilic acid	ferulic acid
AVA-C	OH	OH	OH	5-hydroxyanthranilic acid	caffeic acid

Minerals: Oats contain higher amounts of minerals (2-3%) as compared to other commonly consumed cereals. Potassium, an electrolyte and phosphorus, component of phospholipids are abundant in oats, along with iron, zinc, magnesium & manganese.

Oats consumption improves the overall diet quality with enhanced essential nutrients consumption as oats are one of the most nutrients-dense cereal grains (Gulvady et al. 2014).

Clinical health benefits of oats consumption

Oats are a storehouse of unique nutrients and for decades, numerous scientific studies have established the health benefits of oats in lowering glycaemic response & reducing blood cholesterol levels.

Table 7. Comparative analyses of vitamins in major cereals

Minerals (mg)	Oats	Wheat	Corn	Rice (White)	Rice (Brown)	Jowar	Bajra	Ragi
Calcium	54	34	6	28	23	27.6	27.3	364
Iron	4.7	3.6	3.4	0.8	1.5	3.9	6.4	4.6
Magnesium	177	137	127	25	143	133	124	146
Phosphorus	523	357	241	115	333	274	289	210
Potassium	429	363	287	115	223	328	365	443
Zinc	4	2.6	1.8	1.1	2	2	2.8	2.5
Copper	0.6	0.4	0.2	0.2	0.3	0.4	0.5	0.7
Manganese	5	4.1	0.5	1.1	3.7	1.2	1.1	3.2

Table 8. Mineral content in common cereals (per 100g)

Vitamins (100g)	Oats	Wheat	Corn	Rice (White)	Rice (Brown)	Jowar	Bajra	Ragi
Thiamine (mg)	0.8	0.5	0.4	0.1	0.4	0.3	0.2	0.4
Riboflavin (mg)	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2
Niacin (mg)	1	4.9	3.6	1.6	5.1	2.1	0.9	1.3
Vitamin B6 (mg)	0.1	0.4	0.3	0.2	0.5	0.3	0.3	0.05
Folate (µg)	56	44	25	8	20	39.4	36.1	34.6

a. Effect of oats consumption on Blood glucose levels

The beneficial effects of oats β-glucan on glucose metabolism are well-documented. EFSA approves health claims on oats stating that consumption of approx. 4 g β-glucan (per 30 g of available carbohydrates) from barley or oats, alone or per meal helps lowering blood glucose levels (EFSA, 2011).

Mechanism of Action: Hypoglycaemic effect of oats fibre is attributed to the presence of β-glucan. The β-glucan forms solutions of high viscosity, slowing down the passing of contents to the duodenum and slower digestion of carbohydrates. Due to this, there is delayed digestion leading to delayed glucose release, translating into lower postprandial glycemia and lower insulin requirements. *Clinical Evidence:* In a randomised controlled pilot study, conducted for 30 days, on 298 overweight Type 2 diabetic subjects, the oats intervention group (consuming both 50g/day & 100g oats/day) had a significantly higher reduction in post-prandial blood glucose (PPG) as compared to a control group.

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The intervention was continued for 1 year & it was found that glycated haemoglobin, weight and triglyceride levels were significantly lower in the 100g oats group as compared to the control (Li et al 2016).

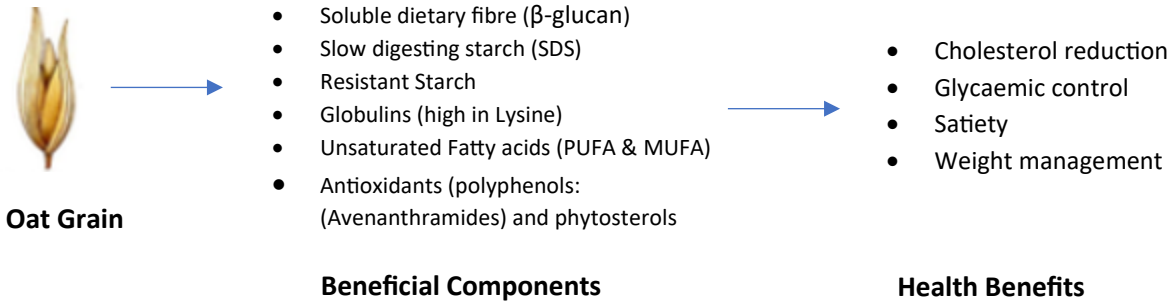

Fig. 6 Beneficial components of oats grain and their reported health implications

a. Effect of oats consumption on Blood cholesterol

Oats β-glucan is a unique soluble fibre that is well-researched and established to lower low density lipoprotein cholesterol (LDL-C) when consumed min 3g/day (EFSA, 2011). Lipid-lowering capacity is attributed to the degree of viscosity and fermentation capability of the soluble fibre.

Mechanism of Action: High Mw β-glucan forms viscous solutions that prolong gastric emptying, and inhibits the transport of triglycerides and cholesterol across the intestine thus decreasing cholesterol uptake from the intestinal lumen. It also binds to bile acids, monoglycerides, free fatty acids and cholesterol, thereby increasing faecal excretion.

The fermentation process in the colon produces short-chain fatty acids (**SCFAs)** which influence the expression of multiple genes regulating lipid & carbohydrate metabolism. β-glucan also regulates the phosphorylation of AMP-activated protein kinase (AMPK), which is a prime enzyme involved in energy exchange (Othman et al. 2011; Kristek A et al. 2018).

Clinical evidence: In a 45-day placebo-controlled trial conducted among hypercholesteraemic, overweight adults, aged 18-65 y, consuming 3g β-glucan/day from oats porridge (80g oats) showed lowering of non-HDL-c & triglycerides (TC) by approx. 13% and 8%, respectively (Xu D et al. 2021). A meta-analysis of 58 RCTs reported a positive correlation between consumption of 3.5g oats β-glucan/day & LDL -C & non high-density lipoprotein (HDL-C) & apo-B as compared to control diets. The reduction in LDL-C levels & apo-B were significant in subjects whose diets contained Oats at levels of min. 3g β-glucan/day, supporting the EFSA allowance (EFSA, 2011) on the consumption of oats for LDL-C reduction (Ho et al. 2016).

b. Effect of Oat consumption on Satiety & management of Weight

Oats or oats products, being rich in dietary fibre require sufficient time, which prolongs the food's exposure time in the oral cavity and allows sufficient time for the transmission of signals that regulate satiety. β-glucan in Oats gives it a unique characteristic, making the contents viscous in the gastric lumen. Increased viscosity increases transit time in the intestinal lumen, which allows adequate time to stimulate the peptides regulating satiety. Oat fibre enhances the activity of CCK, Ghrelin, PYY & GLP-1, hormones that enhance satiety.

Additionally, satiety signals are upregulated by SCFA's produced from the colonic fermentation of soluble fibre in Oats. (Rebello et al, 2016). In a crossover study, the consumption of oatmeal in 48 healthy individuals increased fullness & reduced the desire to eat as compared to isocaloric serve of a ready to eat (RTE) cereal with milk. The study indicated fullness up to 4 hours with Oatmeal, and a lower intake of calories after 4 hours. Higher viscosity & molecular weight of β-glucan coupled with sufficient hydration of oats were major reasons for increased feelings of fullness (Rebello et al, 2016). Higher fullness causes a lower intake of calories, thus helping weight management. Oat starch coupled with soluble fibre, better quality plant protein, micronutrients & unsaturated fatty acids, causes a lower glycaemic

response as compared to many other cereals, especially when cooked without moisture or for less time. Lower blood sugar fluctuations help in reducing the hunger pangs in diabetics.

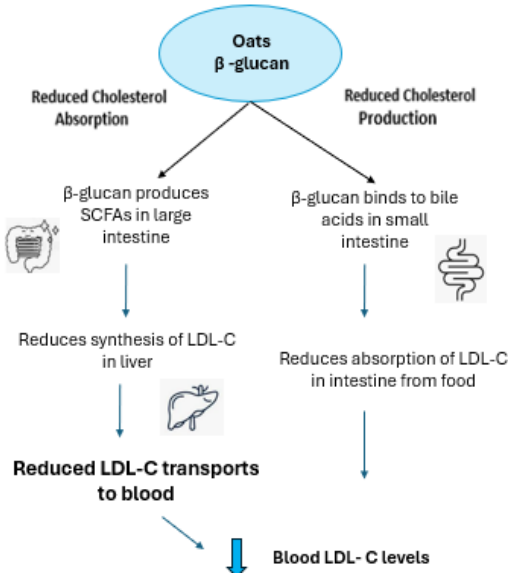

Fig 8. Possible mechanisms for the LDL-C lowering impact of β-glucan (LDL-C: Low Density Lipoprotein cholesterol; SCFA: Short Chain Fatty acids)

Similar observations were made in a study where 37 type 2 Diabetes Mellitus (T2DM) patients, were given 5g oats β-glucan/day with a regular diet. After 12 weeks, there was a significant improvement in HbA1c, HOMA-IR, Sr. insulin & C-peptide, levels along with positive effect on satiety markers such as leptin, GLP-1 & PYY (Pino et al. 2021).

CONCLUSION

Oats offer a diverse range of nutrients and beneficial components and hence, are associated with clinical benefits due to the presence of soluble fibre β-glucan, micronutrients & unique antioxidant, Avenanthramides. Incorporating oats into daily diets helps fulfil the WG and macro-micronutrients requirements, thus providing an effective strategy for reducing the risk of hidden hunger. Unlike maize, rice, or wheat, oats generally retain their WG composition even after processing. Consequently, integrating oats into one's diet may contribute to meeting the recommended fibre intake of 30g/day by the ICMR. Scientific evidence supports that oats consumption can effectively lower cholesterol levels and blood glucose levels, eventually helping reduce the risk of NCDs among Indians. Therefore, including oats as part of a broader spectrum of WG and diverse food groups has the potential to enhance overall health outcomes.

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