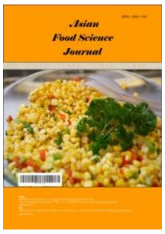


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# Oats: Its Biologically Active Compounds as Functional Food Source

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

Oats are known to be a healthy food for the heart mainly due to their high β-glucan content. Besides, they contain more than 20 unique polyphenols, avenanthramides, which have shown strong antioxidant activity in vitro and in vivo. The polyphenols of oats have also recently been shown to exhibit anti-inflammatory, anti-proliferative, and anti-itching activity, which may provide additional protection against coronary heart disease, colon cancer, and skin irritation. Oats have been labelled as a functional food as they contain β-glucan, minerals, and antioxidants. Owing to their high nutritional value, oat-based food products like bread, biscuits, cookies, probiotic drinks, breakfast cereals, flakes, and infant food are gaining increasing consideration.

*Keywords: Antioxidants; β-glucan; coronary heart disease; functional food; oats.*

## 1. INTRODUCTION

Oats are a significant world crop, and growing recognition of the nutritional value of the oat grain has led to an expanded usage for food purposes. Oats are consumed as a rolled, flaked breakfast cereal throughout the world. Flavour is an important parameter for the acceptance of oat

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products by consumers. Within cereals, oats (Avena sativa) rank sixth in world production and in India, almost 1.0 lakh hectares of land is under oat cultivation as a fodder crop with an average yield of 42 tons/hectare [1]. It is mainly grown as a fodder crop for feeding farm animals. However, today oats are receiving increased interest because of their excellent health-related properties. They are a rich source of soluble fiber, balanced proteins, vitamins and minerals, which are essential for human health [2].

## 2. THE GRAIN

Oat grain has a soft kernel and lipid distributed throughout the seed, which makes its milling process more difficult than wheat and corn. To prevent atmospheric oxidation, the oat is given a hydrothermic treatment before processing. Hull (husk) of oat grain is about 25–30% of the seed (Fig. 1).

## 3. PROCESSING OF OATS

Oats are processed to produce oat-based food products with health-beneficial properties. Fig. 2 illustrates the various processing steps associated with oats.

### 3.1 Milling

Before processing oats into products, the oats are dehulled and groats are subsequently separated and decontaminated. Oat milling is performed to get a good quality appearance and taste. The milling operations consist of cleaning, grading, hulling, ‘hull, fine and groat separation’, and kilning. Oats are graded based on groat length and thickness. The kernels are dehulled using either impact or stone hulling systems. However, impact hulling is more commonly used than stone hulling [3].

### 3.2 Pearling

Pearling technology, also referred to as debranning and pre-processing, was originally used for the polishing of rice and wheat. By integrating pearling with the milling of wheat, improved flour yield was obtained [4]. Laca et al. suggested that pearling could lead to substantial microbial decontamination of wheat grains [5]. Pearling of oat has been studied to a limited extent. These studies demonstrate the high potential of oat pearling for the removal of trichomes that are found to be closely related to aluminium content in oats. Industrial application and control of oat pearling may be easier than in the case of wheat because of their softness and higher lipid content which reduce kernel breakage. Application of pearling technology to oat facilitates separation of β-glucan-rich fractions from pericarp, aleurone, and subaleurone layers of oat [6].

### 3.3 Flaking

Oat groats are mainly flaked. The flaking process involves various unit operations such as cleaning, heat treatment, dehulling, cutting and flaking (or milling). These steps are mainly dependent upon the final oat product and also on the variety of oats (covered or naked) used. The oats are cleaned to remove coarse field trash, dust, etc. which may interfere in further processing. Oats are rich in lipid content and hence oat flour shows high adhesiveness and is difficult to handle. Despite having this disadvantage, oat flakes are the most common whole grain oat product used in the baking industry [7]. Owing to the high amount of lipases, the lipids may be prone to hydrolysis leading to rancidity in the flaked oats. Thus oats for food purposes are heat treated to deactivate the enzymes responsible for changes in oat lipids [8]. Generally, during the heat treatment, the moisture is increased to approximately and the grains are kept at a temperature above 100 °C for 90– 120 min [9]. Additionally, heat treatment provides other benefits such as the destruction of bacteria and fungi and also the development of oat aroma. Oats are graded to have similar-sized grains before they are dehulled. This improves the efficiency of the dehulling process. Steam (99–104°C) is used to increase the moisture content and soften the groats to obtain minimum breakage during the flaking process. Steamed oats develop characteristic oat flavour and steaming also results in the deactivation of enzymes including lipases. In a study, flaking of intact oat groat produced rolled oats of 0.5–0.8 mm thickness. After flaking, the rolled oats were cooled with air to about 45°C and the product had a moisture content of about 9–11.5% [8].

### 3.4 Heat Processing

A typical heat processing operation of oats includes kiln drying and steam stabilization, while superheated steam processing and microwave heating are recent methods used for the processing of oats. Moltenberg et al. (1986) reported that thermal treatment of oats may result in rancid and bitter flavour if processed with hulls [10]. Fors and Schlich reported that the biggest influence on flavour composition was the lipid content and the processing of oats such as heat treatment and milling before or after roasting [11]. Sand roasting is a traditional method of grain processing in India. A variety of whole grains like black gram, barley, rice, corn, groundnuts, etc. are roasted in the hot sand at temperatures varying from 250 to 350°C to produce ready-to-eat snack food [12,13,14]. Maillard reaction is often associated with heat treatment, which is involved in flavour development in oats [15]. Prevention of lipid hydrolysis in oats is the main goal in the manufacture of oat-based products. Though kiln drying and steam processing serve the purpose, novel processing techniques are been explored. Microwave heating is one such technique used to deactivate lipase and lipoxygenase in cereal bran, germ, soybean [16], groundnuts [17], rapeseed [18], and olive oil [19]. Microwave heating is reported to stabilize the oat flour, by enzyme deactivation. Microwave heating at above 150 °C for 15 min, has shown increased phenolic content and antioxidant activity in oat bran extracts [20].

## 4. NUTRIENTS IN OATS

Oat has a well-balanced nutritional composition. It is a good source of carbohydrates and quality protein with a good amino acid balance. Oat contains a high percentage of oat lipids especially unsaturated fatty acids, minerals, vitamins, and photochemical [21].

### 4.1 Oat Starch

Starch constitutes about 60% of the oat grain. It is mainly a constituent of the endosperm. There is a considerable difference observed between the physicochemical properties of oat starch and other cereal starches. Differences in physicochemical properties are also observed in different cultivars of oat. These differences are probably due to differences in the magnitude of the interaction between and among starch chains within the amorphous and crystalline regions of the native granules and by the chain length of amylose and amylopectin fractions of oat starch. Oat starch offers untypical properties such as the small size of granules, well-developed granule surface, and high lipid content [22].

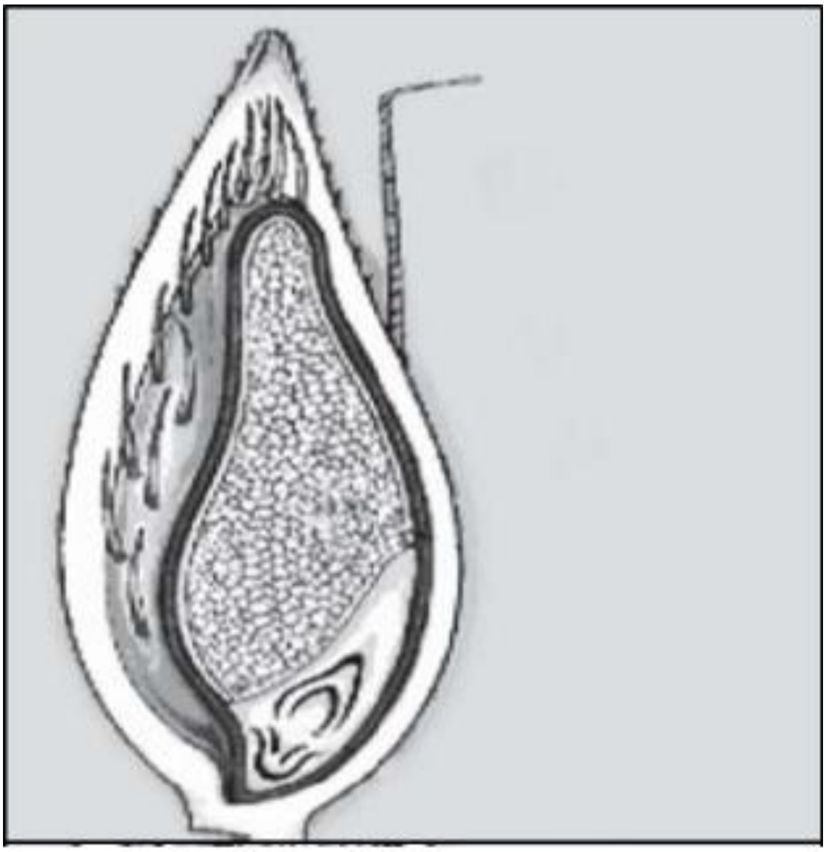

**Fig. 1. Cross section of oat grain . By courtesy of encyclopedia Britannica Inc., copyright 1996**

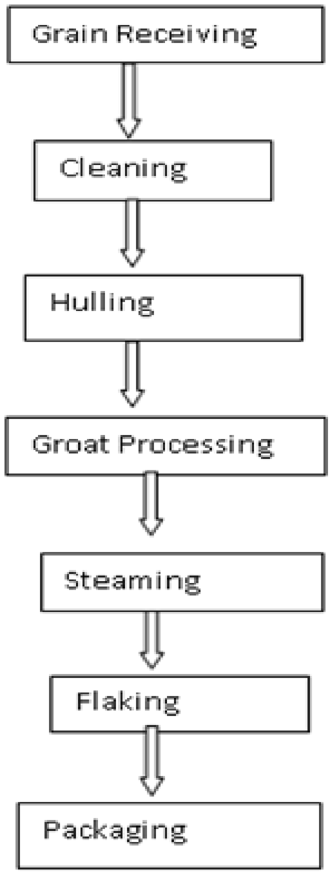


**Fig. 2. Processing of Oats**

## 4.2 Oat Protein

Oat is considered to be a potential source of low-cost protein with good nutritional value. Oat has a unique protein composition along with high protein content of 11– 15%. Cereal proteins have been classified into four types according to their solubility as follows: albumins (water-soluble), globulins (salt water-soluble), prolamins (soluble in a dilute alcohol solution), and glutelins (soluble in acids or bases). Oat protein not only differs in the structural properties but also differs in the distribution of protein fraction in comparison to other cereal grains [23].

## 4.3 Dietary Fibers

Dietary Fibers (DF) are an essential part of the human diet. They consist of many substances of plant origin that are not digested in the human upper gastrointestinal tract. They include polysaccharides such as cereal β-glucan, arabinoxylans, and cellulose. Dietary fibres are located in the cell walls of the grain. The outer layers, the seed coat, and the pericarp contribute significantly to the insoluble dietary fiber content of the grain [23].

Oat β-glucans are components of dietary fiber. Schneeman (2001) suggested that dietary fiber regulates the rate of nutrient digestion and absorption and serves as a substrate for the microflora of the gut and promotes laxation [24].

β -glucan also has good water binding and emulsion stabilizing properties thus it has been used in different food products to improve the textural and rheological properties [25].

## 4.4 Lipids

Oat is a good source of lipids. It contains much higher levels of lipids than other cereals which are excellent sources of energy and unsaturated fatty acids. The majority of lipids of oats are in the endosperm. The fat content of oat ranges from 5.0 to 9.0 % of the total lipid content. The lipid content in an intact kernel of oat stored for 1 year at room temp was found to be stable [20]. due to the protection from endogenous antioxidants such as tocopherols, L- ascorbic acid, thiols, phenolic amino acids, and other phenolic compounds.

## 5. HEALTH BENEFITS OF OATS

Oats have received considerable attention for their high content of dietary fibers, phytochemicals, and nutritional value. It is believed that the consumption of oats possesses various health benefits such as hypocholesterolaemic and anticancerous properties. Oats have also recently been considered suitable in the diet of celiac patients. Owing to their high nutritional value, oat-based food products like bread, biscuits, cookies, probiotic drinks, breakfast cereals, flakes, and infant food are gaining increasing consideration [32].

Oats have recently attracted research and commercial attention mainly due to their high content of β-glucan and compounds with antioxidant activity [25,33,34].

### 5.1 Oats in Coronary Heart Diseases (CHD)

Epidemiological evidence has indicated that a high intake of whole-grain foods is associated with a lower risk for coronary heart disease (CHD) and diabetes [35]. Wholegrain foods contain a significant amount of fiber, which is believed to be the major factor contributing to their beneficial effects on CHD and diabetes. Thus, several epidemiological studies have focused on the association of cereal fibers (representing whole-grain fiber) with the risks of CHD. An inverse relationship has been reported between the high intake of cereal fiber and the risk of myocardial infarction. An early meta-analysis of multiple, controlled studies has suggested that consumption of whole grains including wheat, rice, maize, and oats reduces the risk of CHD slightly better than even fruit or vegetables [36].

Five approved European Food Safety Authority (EFSA) health claims apply to oats. Four relate to the oat-specific soluble fibers, the β-glucans, and concern the maintenance and reduction of blood cholesterol, better blood glucose balance, and increased faecal bulk. The fifth claim concerns the high content of unsaturated fatty acids, especially present in the endosperm, which reduces the risks of heart and vascular diseases. Furthermore, oat starch has a low glycemic index, which is favourable for weight control. Oat-specific polyphenols and avenanthramides have antioxidant and anti-inflammatory properties. Thus, oats can contribute significantly to the presently recommended whole-grain diet [37].

According to Kristina A. Harris whole grains high in viscous fiber (oats, barley) decrease serum low-density lipoprotein cholesterol and blood pressure and improve glucose and insulin responses [38,39]. Furthermore, the health effects of β-glucanas related to cholesterol reduction, improved gastrointestinal function, and glucose metabolism would be achieved at a daily consumption level of 10 g oat β-glucan[40].

**Table 1. Shows the main nutritional components of oats [26]**

| | Components | Properties | Ref. |
|---|---|---|---|
| Proteins | Albumins, globulins, prolamins, and glutenins | Oats are distinct among cereals due to their higher protein concentration and distinct protein composition. The major storage proteins are globulins | [27,28] |
| Carbohydrates | β-glucan, glucose, fructose, pentosans, saccharose, kestose, neokestose, bifurcose, neobifurcose, acid galactoarabinoxylan, *etc* | β-glucan is the most important component because it is a constituent of the dietary fiber obtained from oats. β-glucan has important functional and nutritional properties, and exhibits a high viscosity at relatively low concentrations | [29,30] |
| Lipids | Oat lipids are highly unsaturated and contain several essential fatty acids | Oats, after corn, have the highest lipid content of any cereal. Oat lipids include very high levels of antioxidants | [31,32] |
| Antioxidants | Vitamin E (tocols), phytic acid, phenolic compounds, avenanthramides, flavonoids, and sterols | Antioxidants may reduce serum cholesterol concentrations, and inhibit the growth of certain cancer cells | [32] |

## 5.2 Oats in Coeliac Disease (CD)

The water-insoluble storage proteins of cereals (prolamins) are called “gluten” in wheat, barley, and rye, and “avenins” in oats. Oat avenins do not contain any of the known coeliac disease epitopes from the gluten of wheat, barley, and rye [37].

The avenins in the genus Avena are free of the known CD immunogenic epitopes from wheat, barley, and rye. T cells that recognize avenin-specific epitopes have been found very rarely in CD patients. CD patients that consume oats daily do not show significantly increased levels of intraepithelial lymphocyte cells. The safety and the positive health effects of the long-term inclusion of oats in the gluten-free diet have been confirmed in long-term studies [41].

## 5.3 Oats in Cancer

The high amount of short-chain fatty acids among dietary fiber fractions from oat is believed to possess potent anticancerous activity. In vitro studies imply butyrate exerts multiple effects to modulate gene expression and regulatory effect of apoptosis and cell cycle. This is involved in countering colon cancer [42].

Lunasin peptides isolated from oats are believed to have anti-inflammatory and anticancerous properties [43].

Phenolic compounds are important phytochemicals in oats and function as free radical scavengers and are involved in reducing the risk of atherosclerosis; prevent some forms of cancer and coronary heart disease [33].

# 6. CONCLUSION

Oats are whole-grain food, known scientifically as *Avena sativa*. Oat groats, the most intact and whole form of oats, take a long time to cook. For this reason, most people prefer rolled, crushed, or steel-cut oats. They are a good source of carbohydrates and fiber, including the powerful fiber β-glucan. Oats are loaded with important vitamins, minerals and antioxidant plant compounds. Whole oats are high in antioxidants and beneficial plant compounds called polyphenols. β-glucan in oats helps reduce cholesterol and blood sugar levels; promotes healthy gut bacteria and increases feelings of fullness. Due to the soluble fiber β-glucan, oats may improve insulin sensitivity and help lower blood sugar levels.

# COMPETING INTERESTS

Authors have declared that no competing interests exist.

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