

## Arabinoxylans from psyllium husk: A review

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**Abstract:** Arabinoxylan is a hemicellulose found in cell walls of plants including woods, cereal grains, husk and others. It is comprised of two pentose sugars, arabinose and xylose. Maximum amount of arabinoxylans is present in psyllium husk; a papery layer around psyllium seed. The seeds of monocots contain it in cell wall while the most part is comprised in their endosperm. The yield of arabinoxylan is different ranging between 5 to 8% in whole wheat flour (w/w) and 6.40 to 6.93% in dry malts whilst psyllium husk comprises more than 60% (w/w). The arabinoxylan in psyllium husk is branched molecule additionally comprising of rhamnose (3–5%) and galacturonic acid (5–8%) unlike its other sources. Moreover, the molecular structure of arabinoxylans from psyllium husk makes it gel forming non-fermentable and non-digestible and cereals contain fermentable arabinoxylans that are digestible. Arabinoxylans is partly degraded in malting process. Physicochemical response exhibits that light coloured products are obtained when added in wheat flour along with improved rheological properties. Arabinoxylans is active to prevent and cure various ailments. These characteristics make this substance vital for functional foods and nutraceutical products. Arabinoxylans the active ingredient in Psyllium husk had imperative physiological functions: working as laxative, manages serum lipid profile in hypercholesterolemic people, decreases glucose and Hb A1c concentrations in patients with type 2 diabetes. The arabinoxylans addition in meal, functional food and its administration in nutraceutical products can provide better healthy human livings. The existing literature indicates the research outcomes related to yield, structure, composition and physicochemical response of arabinoxylans exclusive from psyllium husk.

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## 1. Introduction

The nutraceutical and functional importance of food is often associated with the presence of bioactive molecules. Among the group of nutraceutically important foods, dietary fiber and its different fractions have attained immense importance (Saeed et al., 2010). Psyllium seed husk is considered as a laxative (Marlett et al., 2000; Marlett and Fischer, 2002) and a means to lower down the level of serum cholesterol and LDL in hypercholesterolemic adults (Arjmandi et al., 1997; Olson et al., 1997; Anderson et al., 1999). Likewise, it is effective in lowering the glucose concentration in type 2 diabetic patients (Anderson et al., 1999). The health enhancing properties are attributed to its active fraction arabinoxylans; a polysaccharide containing heteroxylan, with main monosaccharides; arabinose and xylose, referred as arabinoxylans (Marlett and Fischer, 2002, 2003; Fischer et al., 2004).

Arabinoxylans are primarily considered the major non-starch polysaccharides of cereals including wheat, rice, maize, rye, oat, barley, millet and sorghum (Izydorczyk and Biliaderis, 1995). These are present in other seeds as well, mainly in the aleuron layer or in covering material as in psyllium seeds. In general, arabinoxylans are hemicelluloses that have linear backbone of  $\beta$ -(1→4)-linked D-xylopyranosyl units, with arabinose side chains (Marlett and Fischer, 2002) including other sugars and uronic acid in traces (Izydorczyk and Biliaderis, 2007).

The arabinoxylans are different in their structural features (Cui, 2001), concentration (Rattan et al., 1994), fermentation, functioning and physiological role (Kennedy et al., 1979; Marlett and Fischer, 2003) depending primarily on its origin. In the food, they work as soluble dietary fiber, which is required for normal body functioning as minimum daily consumption 25g of dietary fiber with at least 6g

soluble fiber is recommended by the US Department of Health and Human Services, (2010). They also work effectively as a functional diet component against physiological disorders like obesity, diabetes mellitus (Ziai et al., 2005; Hartvigsen et al., 2013), hypercholesterolemia (Wei et al., 2009), cancer and problems related mainly with gastro intestinal tract (Bouchoucha et al., 2004 and Ramkumar and Rao, 2005). The use of arabinoxylans for the preparation of functional/nutraceutical foods for the vulnerable groups of the community is gaining attention round the world (Vega-Lopez et al., 2003). A lot of research has been carried out to examine the effect of arabinoxylans from various sources, but there is a need to review the research outcomes of arabinoxylans obtained from psyllium husk. This review will cover the arabinoxylans with respect to source and yield, The article will also reveal the structure, composition, determination, digestibility and physicochemical response of arabinoxylan obtained from psyllium husk.

## 2. Sources and yield of arabinoxylans

The principal source of arabinoxylans is psyllium husk (Saghir et al., 2008) while whole cereal grains like wheat, oat, corn, barley, barley malt, rye, rice, millets, sorghum, guar gum in general are also containing arabinoxylans (Izydorczyk and Biliaderis, 1995).

Psyllium husk contains total dietary fiber and arabinoxylans contents  $76.63 \pm 1.32$  and  $46.71 \pm 2.14\%$ , respectively (Qaisrani et al., 2014). Psyllium husk is comprised of 84.98% of total carbohydrates considering as dietary fiber with the major fraction of arabinoxylan as more than 60% (Guo et al., 2008). Arabinoxylan is 45-60% of the weight of the psyllium husk (Saghir et al., 2008; Van-Craeyveld et al., 2009).

Pritchard et al. (2011) in study on wheat concluded that arabinoxylans in whole wheat flour ranged between 5 to 8%, whereas the refined wheat flour contained only 2 to 3% of this fraction. Concentration of arabinoxylans varies in different parts of wheat grain. 72% of its cell wall on w/w basis was arabinoxylans while 60 to 69% of non-starch polysaccharides in wheat bran comprised of this fraction (characteristically insoluble) and in endosperm 88% of non-starch polysaccharides was the arabinoxylans (mostly water soluble). Shiiba et al. (1993) conducted a study on purification and extraction of wheat arabinoxylans. It was concluded that water soluble hemicellulose of wheat bran consisted of 86.4% of arabinoxylans. Among the non-

starch polysaccharides in wheat bran arabinoxylans are in the range of 64 to 69% as stated by Ring and Selvendran, (1980). Previously, Maires and Stone, (1973) deduced that in non-starch polysaccharides of wheat endosperm about 88% were arabinoxylans.

Debyser et al. (1997) studied six barley malts regarding their arabinoxylans content and its hydrolyzing properties. They found that total arabinoxylans was in the range of 6.40 to 6.93% in dry malts. The study results also revealed that water-extractable arabinoxylans was between 0.49 to 0.69% where the wort comprised of 0.62 to 0.93% representing 10 to 14% of total arabinoxylans content in dry malt. In barley, the cell wall of endosperm comprised of 20% arabinoxylans on w/w basis.

Extraction yield of arabinoxylan is affected by certain factors such as time, temperature, pH and concentration of media (Marlett and Fischer, 2003). Van-Craeyveld et al. (2009) reported that extraction yield increased from 4 to 16% as temperature increased from 4 to 50°C, but a diminishing trend was observed in yield afterwards. Moreover among different pH 6.7, 7.8 and 13, the maximum extraction yield was found at pH 13.

## 3. Structure and composition of arabinoxylans

The husk yield is 10–25% of the dried psyllium seeds and has water holding capacity up to ten folds of its dry weight. The mucilage is colorless, odorless and tasteless (Anderson et al., 2000). Considering chemical composition, the resultant husk is containing 6.83% moisture, 0.94% protein, 4.07% ash and 84.98% of total carbohydrates (Guo et al., 2008; Yu et al., 2009). However, the fractional composition of the husk arabinoxylan was as rhamnose 1.50%, arabinose 21.96%, galactose 3.76%, glucose 0.64%, xylose 56.72%, and mannose 0.40%. Interestingly, the arabinoxylan from psyllium husk contains additional residues such as rhamnose (3–5%) and galacturonic acid (5–8%) as reported by Van-Craeyveld et al. (2008).

Shiiba et al. (1993) estimated the molecular ratio of arabinose and xylose in arabinoxylans of wheat bran as 44.9 and 41.5%, respectively, while comprising 6.8, 5.2, 0.27 and 7.3% glucose, glucuronic acid, total ash and crude protein contents, respectively. Another study explored the arabinoxylans contents as 43% xylose and 37.1% arabinose, i.e., 80.1% are pentoses, while the glucose and uronic acid were 9.4 and 4.3%, respectively (Brillouet and Mercier, 1981).

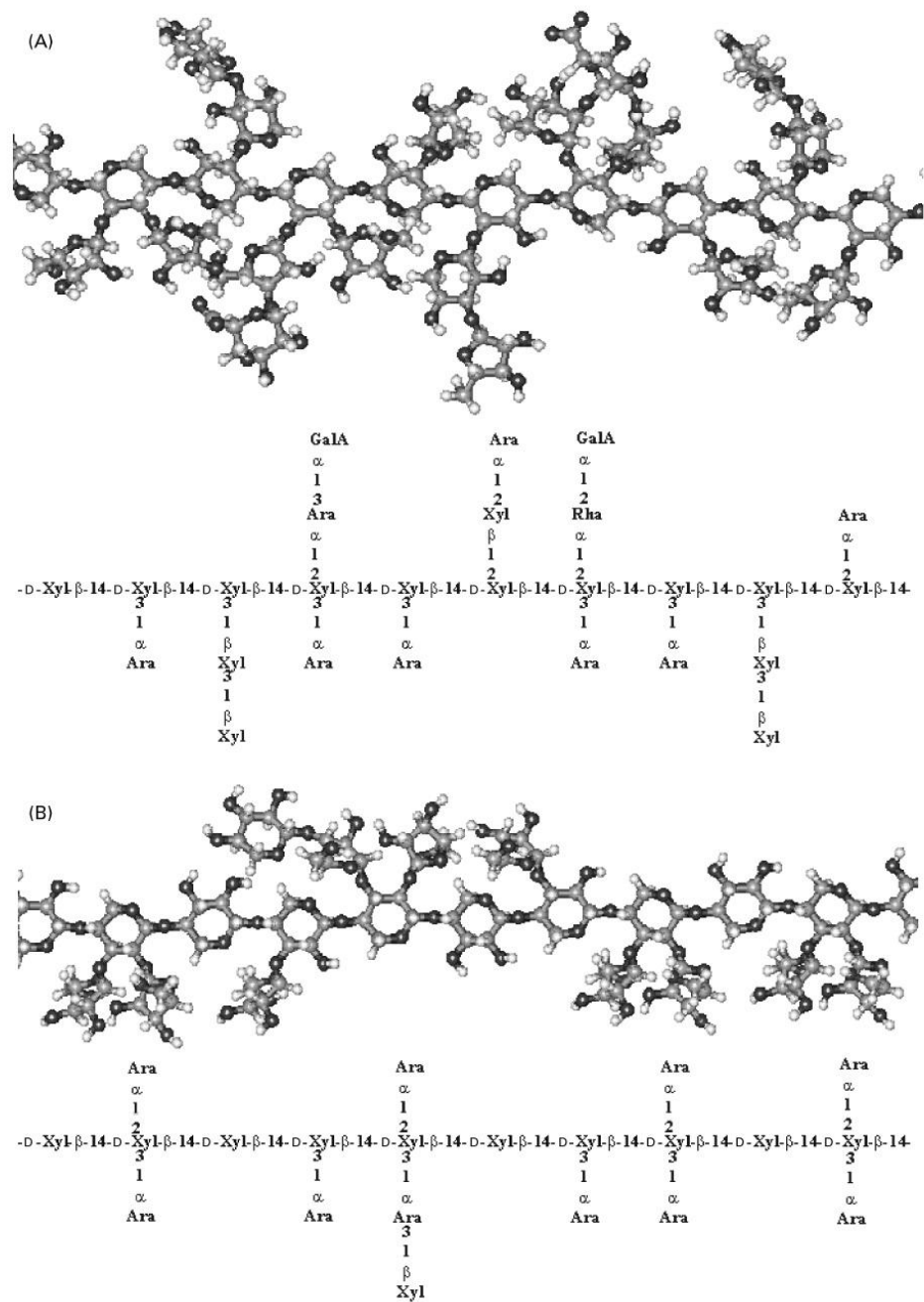


Fig. 1: structure of arabinoxylan exclusive from psyllium husk (Edwards et al., 2003).

Psyllium husk arabinoxylan is a highly branched polysaccharide constituted mainly of xylose (74.6%) and arabinose (22.6%) on its sides constructing the branches again with xylose. The fractionation indicates that it also contains traces of other sugars like mannose, rhamnose, glucose and galactose (Guo et al., 2008).

Arabinoxylans have a main chain of densely substituted β (1→4) linked xylopyranose residues.

Furthermore, arabinofuranose and xylopyranose residues or their short side chains are attached at different positions in the main chain of xylopyranose residues ultimately giving it a branched pattern in this way (Edwards et al., 2003; Fischer et al., 2004).

The methylation and NMR data support that branches have sequence of arabinose and xylose as L-Araf-α-(1→3)-D-Xylp-β-(1→3)-L-Araf. Only traces of other sugars like rhamnose, glucose and galactose

are present along with uronic acid (Marlett and Fischer, 2002; Edwards et al., 2003). Arabinoxylans has molar mass of 3,64,470 g/mol. It shows high swelling ability in water and its sugars with three OH groups making it more functional. Therefore, the compound can yield tri-, di- and mono-O-functionalized products in the form of carboxymethylated units (Saghir et al., 2008), leaving about 35% of non-reducing terminal residues (Marlett and Fischer, 2003). Similarly, Edwards et al., (2003) found the structural features as L-Araf-(1→3)-[D-Xylp-(1→4)]-2-D-Xyl in the residues fabricated by enzymatic digestion of extract from the psyllium husk. Depolymerization by  $\alpha$ -arabinofuranosidase indicates tetra saccharide arabinose units as  $\alpha$ -anomers, but it is not confirmed for internal arabinose. The results from NMR spectroscopy and HPLC described that it contains 74.8% Xylp and 23.2% Araf.

#### 4. Determination of arabinoxylans

Arabinoxylans contents of husk and food samples are initially isolated by using alkali method (Cleemput et al., 1995). The arabinoxylans fiber thus obtained is finally dried in freeze drier that are derivitized for monosaccharide determination (Vallance et al., 1998). The analysis is carried out by using gas chromatography (Agilent 6890 GC technology) equipped with Microsoft detector (Agilent 5973 MS Detector), while DB-5 column (30 m  $\times$  0.25 mm ID and film thickness of 0.25 $\mu$ m, Agilent, Palo Alto, CA, USA) is used with methyl polysiloxane polymer phase. Helium is used as carrier gas at constant flow rate of 1.3 mL min<sup>-1</sup>. The acquired data is processed with HP-Chemstation Software (Mendeiros and Simoneit, 2007).

#### 5. Digestibility

Arabinoxylans obtained from psyllium husk is resistant to fermentation as compared to those extracted from wheat, oat or barley. Linear chain of xylose is fermented till a typical branch point is reached. At this point, exoxylosidases and xylanases are required for supplementary digestion. Eventually, no further breakage occurs in the remaining structure. Fischer et al. (2004) reported that the factors responsible to oppose enzymatic degradation are higher degree of branching and/or the remarkable linkage pattern of polysaccharides.

Comparison between arabinoxylans exclusive from cereal group and that of psyllium fiber revealed that later is a non-fermentable gel forming carbohydrate, whereas the former is well documented for fermentation ability (Kennedy et al., 1979; Marlett and Fischer, 2003). Digestibility and related

characteristics of arabino xylan can be modified. Carboxymethylation of arabinoxyaln with monochloroacetic acid in alkaline conditions showed to enhance the thermal stability, increased crystallinity and decreased viscosity (Bhatia and Ahuja, 2015). Arabinoxylans acquired from psyllium husk is used to get ethyl arabinoxylans (EAX) by treating husk with ethyl iodide to change its viscosity. The natural viscosity of gum may change because of different reaction conditions like reagents, their amount, slurry medium and structure of EAX in solution. The molecular structure of EAX makes it resistant to cleavage by intestinal micro flora. Digestion of EAX may be the function of enzymes released by colonic microbes (Varady et al., 2005).

#### 6. Physicochemical response

Arabinoxylans produce different physiochemical response in foods, normal human subjects, vulnerable groups and animal modelings. Arabinoxylans not only influences the functional properties of psyllium husk, but also affects the rheology of the product. Rakha et al. (2010) reported that addition of arabinoxylans in dough increased water holding capacity, which improved bread volume, crumb color and gas holding capacity, thus ultimately enhanced shelf life.

Enhancement in water solubility associated with arabinoxylans addition in bread is linked with its abilities of forming a cross link within chain and interaction with solvent. Saeed et al. (2010) reported that addition of arabinoxylans in bread increased dough consistency and resistance, thus decreased the mixing time without any adverse effect on bread quality. In a study by Lu et al. (2000) three wheat breads containing 0, 6 or 12 g of arabinoxylans fibre were evaluated. The results showed that arabinoxylans rich bread was as pale as 50% whole wheat bread as evaluated by the volunteers for colour analysis. Although the pentosans in the grains are present in small amounts, they are surely of immense technological importance with respect to their contribution in the baking quality of wheat and rye, as well as the brewing traits of barley.

Hemalatha et al. (2013) reported improved rheological properties of dough and in chapatti making with 0.25 and 0.5 g / 100 g of arabinoxylans added to the flour. The addition of isolated arabinoxylans from good chapati making wheat varieties to poor chapati making varieties gained higher scores for soft texture and overall quality.

Arabinoxylans dietary fiber show considerable health returns especially to alleviate type 2 diabetes

mellitus, cholesterol reduction, immunomodulatory action, prebiotic effect and increased absorption of some minerals (Mendis and Simsek, 2014). Marlett and Fischer, (2003) related the highly branched polysaccharide with about 35% of non-reducing terminal residues that are medicinally important against high cholesterol, diabetes mellitus, constipation, diarrhea and inflammatory bowel disease-ulcerative colitis. Alabaster et al., (1997) reported in epidemiological studies a strong protective effect of low fat, high fiber and high calcium diet on oncological incidences.

In a clinical trial three breakfasts containing bread supplemented with 0, 6 and 12% arabinoxylans, jam and margarine with same calorific value were administered to healthy people with the objective to determine the effect of arabinoxylans on the postprandial glucose and insulin concentrations. The blood tests revealed that incremental area under the curve (IAUC) for glucose was 20.2% and 41.4% less comparing with that of control breakfast containing 0% arabinoxylans. While decrease in IAUC for insulin noted was 17% and 32.7% for 6 and 12 g arabinoxylans containing breakfasts. They deduced that increasing arabinoxylans in breads decreased postprandial glucose concentration (Lu et al., 2000).

Zhong et al. (2000) reported improved postprandial glucose and insulin responses due to consumption of arabinoxylans-rich fiber diet in Type 2 diabetes mellitus. It had been also reported that addition of arabinoxylans, obtained from maize, at a level of 10g / d to the diet for 6 months improved glucose responses and hemoglobin A1c levels in diabetic obese people (Hanai et al., 1997).

Hartvigsen et al. (2013) fed 15 subjects suffering from metabolic syndrome with test foods providing 50 g of digestible carbohydrates; wheat bread with concentrated arabinoxylans or  $\beta$ -glucan, rye bread with kernels and wheat bread as control. The results of study showed that  $\beta$ -glucan and rye bread with kernel, induced lower initial glycaemic responses when compared with the control meal, whereas, arabinoxylans decreased the glucose peak value only.  $\beta$ -glucan bread decreased insulin responses more than arabinoxylans bread.

The psyllium produced dose and time dependent cholesterol lowering effect in mild to moderate hypercholesterolemic subjects but not in normal subjects conferring it useful as an adjunct in diet therapy for managing hypercholesterolemia (Wei et al., 2009). Murad et al. (2011) studied the effect of psyllium husk fiber on lipid profile of primary

hyperlipidemic subjects for three months and concluded that psyllium husk is a dynamic mediator to manage hyperlipidemia. Psyllium husk may be involved in lowering the activity of cholesterol ester transfer protein and thereby increase in the low density lipoproteins (LDL) receptors activity proposing another route to reduce LDL levels (Shreshtha et al., 2006).

Hypercholesterolemia and hyperglycemia both promote increased glycosylation of hemoglobin due to higher blood glucose levels. Nevertheless, reduction in blood glucose level resulting decrease in HbA1c and this may be achieved by using control diet. Cicero et al. (2010) evaluated long term effect of psyllium husk and guar gum supplementation on metabolic syndrome modules in a comparative study and results deduced that psyllium could be a better choice for managing cardiovascular risk factors than guar gum by managing triglycerides and blood pressure.

## 7. Conclusion

Conclusively, among other plant sources psyllium husk is the richest source of arabinoxylan. The molecular structure and composition of arabinoxylan varies amongst different sources. The arabinoxylan can be added in foods for the preparation of functional food to maintain the lipid profile and glucose concentration. In the nutshell, the therapeutic food containing arabinoxylan is effective to control dyslipidemia and hyperglycemia. It is inferred through the discussion that arabinoxylan enriched foods may be introduced in diet based therapy to combat lifestyle-related disorders.

**Competing Interests:** The authors declare that there is no potential conflict of interest.

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