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THE CURRENT TRENDS AND FUTURE PERSPECTIVES OF ARABINOXYLANS PREBIOTICS RESEARCH: A REVIEW

Abstract

The development of new physiologically functional ingredients allows us to expand the range of these additives and to attract additional non-traditional sources of raw materials. Prebiotics are non-digestible food ingredients that stimulate the growth of probiotic microorganisms in the gastro-intestinal tract. The chemical nature of the most prebiotics are carbohydrates nature polymers: dietary fibers and nondigestible oligosaccharides. Among non-starch polysaccharides, arabinoxylan (AX), arabinogalactan (AG), and β-glucan are of paramount importance. Arabinoxylans are mainly found in cereals grains, for example, wheat, rye, barley, oat, rice, and sorghum.

The current study is a review of literature and authors' own research on biosynthesis, chemical structure, production, physicochemical and physiological properties of arabinoxylans. The structure and molecular weight of AX are vital determinants of their physicochemical, technological and physiological properties. In the article is illustrated in detail the biosynthesis of arabinoxylan in a plant tissue, which makes it possible to understand the formation mechanism of complex structure of these polysaccharides. The main part of cereal grains arabinoxylans are contained mainly in the cell walls of starchy endosperm and the aleurone layer, in the bran tissues, and in the husk of some cereals. The amount of arabinoxylans in a particular tissue depends on the genus and species. However, the degree of branching was found to be lower in arabinoxylans from aleurone than in that from original bran. The molecular structure of arabinoxylans from wheat, rye, and barley is less complex than that from rice, sorghum, finger millet, and maize bran, since their side branches contain, besides the arabinose residues, small amounts of xylopyranose, galactopyranose, and α-D-glucuronic acid or 4-O-methyl-α-D-glucuronic residues.

In the review analyzed methods of obtaining water-soluble and water-unsoluble AX from different agricultural by-products. Water-soluble AX were extracted with a high-temperature treatment combined with followed enzymatic starch removal. After the hot water extraction, non-soluble fibers and protein fractions were separated and the washed fiber fraction was further treated with alkali (NaOH) solution with different solid to liquid ratios. Also there are described the technological properties of AX that were obtained from different cereals.

During the enzymatic hydrolysis of AX are formed arabinoxylanoligosaccharides (AXOS), consisting of arabinoxylooligosaccharides and xylooligosaccharides (XOS). This process is a base of the production of prebiotic arabinoxylooligosaccharides from cereals and cereal by-products. This review mainly focuses on the perspectives of using the arabinoxylans as a raw material for obtaining oligosaccharides-prebiotics.

Key words: *prebiotics, arabinoxylans, cereals, oligosaccharides, xylooligosaccharides, Lactic acid bacteria, Bifidobacteria.*

Introduction

The market potential for foods that can improve the well-being and health of consumers improves the interest in developing the functional foods. One of the popular functional ingredients are prebiotics. Prebiotics are generally defined as non-digestible polysaccharides and oligosaccharides, which promote the growth of beneficial lactic acid bacteria in the colon and exert antagonism to *Salmonella* sp. or *Escherichia coli*, limiting their proliferation. The prebiotics concept were elaborated by certain criteria viz. resistance to gastric acidity, hydrolysis by mammalian enzymes and gastrointestinal absorption; fermentation by intestinal microflora and selective stimulation of the growth, and/or activity of intestinal bacteria associated with health and wellbeing. There exists an array of prebiotics with various origin and chemical properties. The existing prebiotics and classified them based on a set of common criteria [*1*]. Inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS), lactulose and polydextose are recognized as the established prebiotics, whereas isomaltooligosaccharides (IMO), xylooligosaccahrides (XOS), and lactitol are categorized as emerging prebiotics. Chicory root inulin-derived (FOS), wheat bran-derived arabino-xylooligosaccharides (AXOS) and xylooligosaccharides (XOS) proved to have huge applications [2, 3].

This review work does not intend to provide an exhaustive revision of the many works published so far on chemical composition, structure and food application of arabinoxylans (AX). The aim of the present work is provide an overview of the different strategies in the new field of specific functional ingredients, discussing their advantages and drawback. Besides, some ideas about the foreseen development and applications of AX in this new field are also provided.

Biosynthesis of arabinoxylans

The exact mechanism of arabinoxylans synthesis is studied relatively little. AX as other polysaccharides are the products of synthases and glycosyl transferases and, as such, are secondary gene products. AX as other hemicelluloses are synthesized within the cell in the Golgi apparatus and endoplasmic reticulum [4]. The immediate donors of monosaccharides for synthesis of AX are UDP-D-Xyl*p* and UDP-L-Ara*f*, formed from UDP-D-Glc*p* by the action of appropriate epimerases. Some generalizations can be made concerning the mechanism of arabinoxylans polymerization (Fig. 1). The processing of polymerization can be divided into three steps: chain initiation, elongation, and termination. The first sugar donation is not to a free monosaccharide, but to a protein or lipid primer. Tailward growth, i.e., addition of the new residue to the nonreducing end of the chain, has been generally accepted as the direction of chain elongation. Recently, a β-(1→4)-xylosyl transferase, isolated from the microsomal membranes of the developing barley endosperm, has been shown to transfer xylose from uridine

5'-diphosphoxylose (UDP-Xyl) into an exogenous xylooligosaccharide chain (derivatized at the reducing end) [5]. Repeated attachment of xylose residues occurred at the nonreducing end of the pyridylaminated-xylotriose chain through β-(1→4) linkages. During the stepwise addition of the xylose residues to the growing polymer chain, a stage must be reached that involves the addition of the branching points. Arabinose residues are incorporated simultaneously with the polymerization of the xylan backbone that is based on the *in vivo* studies on xyloglucans and glucuronoxylans [4]. Though, the necessity of separate arabinosyl transferases is not clear.

Feruloyl groups are attachmented to arabinoxylans by transacylation, and the polysaccharides are feruloylated co-instanta-neously with the polymerization processes within the endomembrane system [4, 5]. The cross-linking of the feruloylated arabinoxylans also may come after their deposition in the cell walls. It is also suggest that when arabinoxylans are initially deposited into walls, the xylan backbone is heavily substituted with arabinosyl residues. Thereafter, the action of arabinofuranohydrolases removes the arabinosyl residues [6]. These postdeposition processes, debranching and cross-linking, lead to changes in physicochemical properties of arabinoxylans, such as solubility or capability to interact with other cell wall polysaccharides, thereby allowing the plant to control the tissue cohesion, cell expansion, and permeability of the cell walls to metabolites and pathogens.

Unfortunately, it is the least studied the mechanism of chain termination, that immediate controls the longness of arabinoxylan chains. The rates of vesicle movement and fusion with plasma membrane play some role in determining the degree of polymerization (DP) of cell wall polysaccharides that was floated by [4]; however, no evidence exists to support this proposition. The formation of these polymers is not strictly regulated and may depend on several factors that is issue at the numerous and complex events involved in biosynthesis of arabinoxylans.

Raw materials of arabinoxylans

The main source of arabinoxylans are all major cereal grains (wheat barley, oats, rye, rice, sorghum, maize, and millet), as well as the other plants (psyllium, pangola grass, bamboo shoots, and rye grass) [4, 7]. The main part of cereal grains arabinoxylans are contained mainly in the cell walls of starchy endosperm and the aleurone layer, in the bran tissues, and in the husk of some cereals. The amount of arabinoxylans in a particular tissue depends on the genus and species. According to the table 1, the main part of aleurone layer, starchy, and cell walls of wheat rye endosperm is formed from arabinoxylans (~60 to 70%). But the total quantity of arabinoxylan in endosperm of these grains is lower than that of bran. In barley, the starchy endosperm cell walls contain only about 20 to 40% arabinoxylans while the aleurone cell walls are formed mainly from (60 to 70%) of these polysaccharides and a much greater amount from β-glucans. The fine molecular arabinoxylans structure depends on the polymers that are composed their structure. The husk and bran of cereal grains may contain the acidic arabinoxylans (glucuronoarabinoxylans) that are formed from glucuronic acid, arabinose and xylose residues. Genetic and environmental are the most influential factors of the arabinoxylans level in cereals. Among the cereal grains, rye has the highest content of arabinoxylans, followed by wheat and barley (Tab. 1) [4, 7, 11].

It is shown that translocation of wheat, with the short arm of the IB chromosome of wheat replaced by the short arm of the 1R chromosome of rye (1B/1R gene), increases the content of water-soluble arabinoxylans, but does not affect the amount of total arabinoxylans in comparison with standard wheat. According to the other researches, the content of water-extractable arabinoxylans in rye is controlled by many factors scattered throughout the genome. Whereas chromosome 3R is responsible for reduced arabinoxylan level and chromosomes 2R, 5R, 6R are responsible for increased its content. Other studies are explained the significance of genetic and environmental variations in arabinoxylan content for durum wheat and barley [4, 10]. It was reviewed the effect of harvest year on the content of dietary fiber and its composition in seven rye varieties grown in Denmark. The content of total and water-extractable arabinoxylans were higher (27 to 55% of total variance) than those associated with genotype effects (14 to 19% of total variance) in

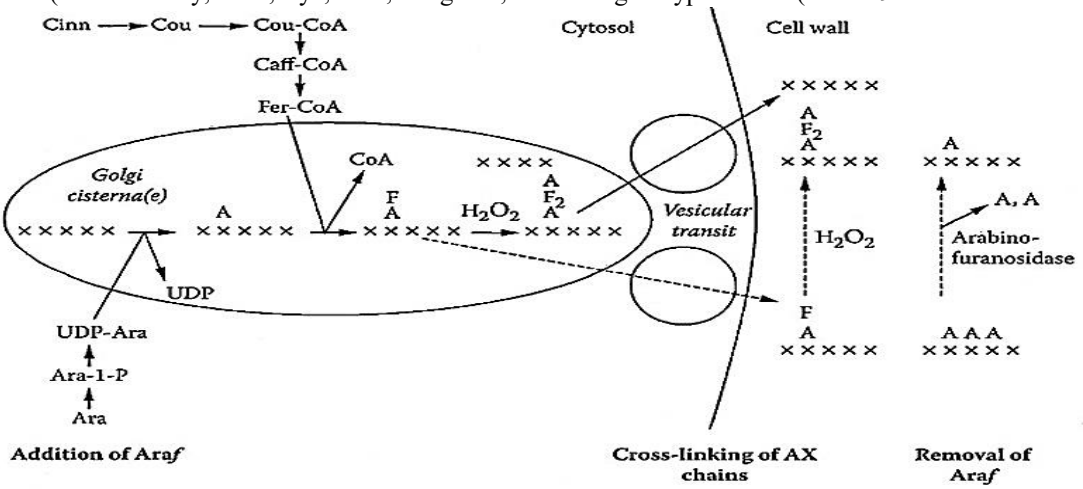

Fig. 1 – Biosynthesis of arabinoxylans

X - xylose residues; A - arabinose residues; F - ferulic acid residue; F2 - diferulic acid; Cinn - cinnamic acid; Cou - coumaric acid; caff - caffeic acid; Fer - ferulic acid [4].

Table 1

Content of total and water-soluble arabinoxylans in various grains and grain tissues

Source		Total arabinoxylans, (%)	Water-soluble arabinoxylans, (%)
Barley	Whole grain	6.11	0.35
	Whole grain	3.4-4.1	-
	Whole grain	-	0.40-0.88
	Pearled grain	4.45	0.27
	Pearlings	14.14	0.54
	Pearled flour	-	0.3-1.08
Wheat	Whole grain	5.77	0.59
	Whole grain	-	0.38-0.83
	Bran	19.38	0.88
	Flour	1.37-2.06	0.54-0.68
	Durum wheat	4.07-6.02	0.37-0.56
Rye	Whole grain	7.6	-
	Whole grain	8-12.1	2.6-4.1
	Bran	-	1.7
	Flour	3.2-3.64	2.2-2.65
Oats	Whole grain	2.73	0.17
	Hulls	8.79	0.40
	Bran	3.50	0.33
	Pearled grain	3.00	0.15
Rice	Whole grain	2.64	0.06
	Hulls	8.36-9.24	0.11-0.12
	Bran	4.84-5.11	0.35-0.77
Sorghum	Whole grain	1.8	0.08
	Pearlings	5.4	0.35
—	Corn bran	29.86	0.28
	Soybean		1.33
	Soybean hulls	13.10	

yearly variations. Among five rye varieties grown in Finland were also found a yearly differences in the total arabinoxylans content [11]. A wet and cold season caused the high arabinoxylan content in small rye kernels. The effect UV light on increasing of cross-linking in arabinoxylans degree was not clearly determined in their influence on the total arabinoxylans content.

The changes in the amount and composition of arabinoxylans in cell walls of wheat coleoptiles grown under continuous hypergravity conditions was investigated [4]. The amount of arabinoxylans per unit length of coleoptiles increased under hypergravity conditions. As a result of continuous hypergravity is observed the increasing of amount of the acidic arabinoxylans (glucuronoarabinoxylans) and ferulic acid-cross-linked arabinoxylans.

The chemical structure of arabinoxylans

Arabinoxylans are builtfrom linear (l→4)-β-D-xylopyranosyl chains which are attached with α-L-arabinofuranosyl residues as side branches. Arabirtose residues can be attached to xylose units at the O-2, O-3, or both O-2,3 positions, resulting in four structural elements in the molecular structure of arabinoxylans: monosubstituted Xyl*p* at O-2 or O-3, disubstituted Xyl*p* at O-2,3, and unsubstituted Xyl*p* (Fig. 2) [4].

The source of arabinoxylans influence on the relative amount and the sequence of distribution of the structural elements vary. The majority of arabinofuranosyl residues in arabinoxylans are present as monomeric substituents; however, a small proportion of oligomeric side chains consisting of two or more arabinosyl residues linked via l→2, l→3, and l→5 linkages have been reported [7]. The molecular structure of arabinoxylans from wheat, rye, and barley is less complex than that from rice, sorghum, finger millet, and maize bran, since their side branches contain, besides the arabinose residues, small amounts of xylopyranose, galactopyranose, and α-D-glucuronic acid or 4-O-methyl-α-D-glucuronic residues (Fig. 2). Barley husk arabinoxylans are constituted about 4% of glucuronopyranosyl residues and are also present in arabinoxylans from wheat bran [9].

As were shown on the Fig. 2 the molecular structure of water-soluble wheat endosperm arabinoxylans has confirmed the generally linear structure of arabinoxylans. However, it also revealed that a small fraction (~15%) of the polymers might, in fact, be branched [4, 9]. These branches were composed of β-(l→4)-linked xylose residues, and they appeared to be randomly located along the chain. The increasing length of the molecules increases the probability of their presence and about 1% of the branched chains contained more than one branch.

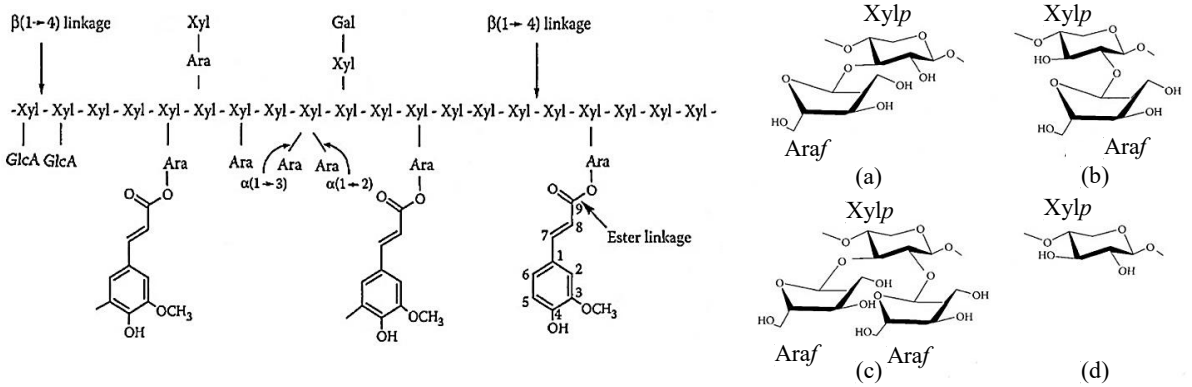

Fig. 2 – General structure of arabinoxylans and their structural elements: *(a) monosubstituted Xy]p at O-3, (b) monosubstituted Xylp at O-2, (c) disubstituted Xylp at O-2,3, (d) unsubstituted Xylp*

The physiologically active gel-forming polysaccharides of psyllium husk (*Plantago ovata* Forsk) contain the neutral arabinoxylans, that are structured from mainly arabinose - 22.6% and xylose - 74.6% residues, and traces of other sugars. But the structure of these arabinoxylans is significantly different from arabinoxylans in common cereals.

Common methods of arabinoxylans production

The widely used approach to isolating arabinoxylans from various plant materials involves aqueous or alkali extraction. The arabinoxylans isolated from the cell wall matrix are water soluble; however, the other arabinoxylans are cross-linked with structural constituents of cell wall and they are insoluble in an aqueous environment. Some of the cross-links are noncovalent and, while individually weak, but their large numbers could reduce the polysaccharides solubilisation (e. g., hydrogen bonds). The other cross-links are covalent and arabinoxylans cannot be easily extracted from the plant materials with water and requires harsher treatments with alkali solutions as well as physical entanglements [12].

It was obtained water-soluble and insoluble arabinoxylans from wheat flour which was mixing with water (50kg/250L). The soluble arabinoxylans were separating from the insoluble residue by centrifugation, and the supernatant were heat treating. The insoluble residue was treated with protease and amylase to solubilize the initially water-unextractable polymers. The yields of water-soluble and -insoluble arabinoxylans ranged from 100 to 200g and from 250 to 350g, respectively [4, 7]. The obtaining of water-extractable arabinoxylans from rye involved a grinding of whole meal, its mixing with deionized water (10kg/100L) and stirring at room temperature (90 min) with followed heat treatment (130°C) to inactivate the endogenous enzymes. After decanting of the supernatant, the water-extractable arabinoxylans were purified by treatments with a heat-stable α-amylase, protein coagulation, and partial concentration by heat evaporation. The yields of arabinoxylans were 54%. The large-scale isolation of highly purified arabinoxylan-enriched cell wall material from wheat endosperm is based on dough kneading in combination with wet sieving. It was developed a method for preparation of cell wall material enriched in arabinoxylans based on wet sieving of wheat flour in aqueous ethanol to remove starch granules, followed by sonication or removal of starch and intracellular proteins by organic solvents to improve the purity of the preparations [4, 13, 14].

The processing of agricultural by-products into arabinoxylan preparations has high prospects for the utilization of organic waste and high economic effect. Such by-products as brewer's (spent) grain, wheat or rye bran, sugar beet pulp, corncobs, and banana peels are the potential sources of arabinoxylans. They are rich in noncellulosic polysaccharides and arabinoxylans are their primary component. Combination of delignification (with 37% sodium chlorite) and alkali extraction (with 43% sodium hydroxide) allows us to obtain arabinoxylan preparations from de-starched wheat bran. The extracted arabinoxylans were purified by a microfiltration and dried by an atomization system, the yield and purity of this preparation were 13 and 75%, respectively. The flow scheme for extraction of AX from wheat bran is shown at the Fig. 3 [4].

It is used the combination of various physical treatments (extrusion and high shear) with the different endoxylanases fermentation to investigate the release of high molecular weight arabinoxylans from rye bran. Arabinoxylans, that were obtained by the rye bran extrusion at high temperature (~140°C) and extracted in the presence of endoxylanase from *Bacillus subtilis*, had a low molecular weight and ability to form gels [15]. The use of hydrolytic enzymes to assist the extraction of arabinoxylans from brewer's grain and wheat bran has also been explored. The using of an enzyme preparation from the thermophilic fungus *Humicola insolens* (endoxylanases and feruloyl esterases) proved efficient in releasing ferulic and diferulic acid residues and solubilizing AX present in these by-products [4].

The content of arabinoxylans in the feed can also be increased by physical grain fractionation. The location of arabinoxylans in cereal grains and their interactions with other grain constituents influence commercial processing, such as milling and isolation procedures aiming at obtaining arabinoxylan-enriched fractions [4, 15]. As a consequence of variable concentration of arabinoxylan in various grain tissues, milling leads to fractions differing in arabinoxylan content. The fractions varied in the content and composition of dietary fiber; a wide range of arabinose-to-xylose (Ara/xyl) ratios and the proportions of soluble-to-insoluble arabinoxylans implied that variations in arabinoxylans' structure are shown in Tab. 2 [16]. Thereby the most arabinoxylan-enrich fraction of rye is a pericarp layer – 39.5% of total AX and the endosperm fraction has the less – 4.2%.

Honcu I. et al. are represented the technology of obtaining AX from wheat bran. Starch and cold water-soluble compounds were separated by aqueous suspension and wet sieving. The subsequent extraction was performed either in a stirred autoclave with water under elevated pressure or in an alkaline medium with hydrogen peroxide. The solids of the bran were removed from the aqueous slurry by centrifugation. The supernatant was preconcentred by ultra- and diafiltration (polysulfone membranes with a molar cut off of 10,000 g/mol) to separate AX from the low molecular weight compounds. AX was subsequently precipitated from the solution by addition of 96% ethanol with a mass ratio of 3.2 to 1. To increase the shelf-life of the final products they were freeze or spray dried. Using hydrogen peroxide in an alkaline medium a high purity AX (69.8% in d.m.) were obtained. The isolated AX is excellent soluble in cold water and can be used such as a thickening agent in the food industry or for technical purposes. By using water in a temperature range of 147-163 °C as an extraction medium, the purity of the final products was considerable lower (47.3 - 58.6% AX in d.m.). The cold water solubility was poor [17].

Physicochemical, technological and physiological properties of arabinoxylans.

The conformation of an unsubstituted xylan bears some resemblance to that of other β-(l→4)-linked polysaccharides, such as cellulose or mannan. The single hydrogen bond between two adjacent xylosyl residues

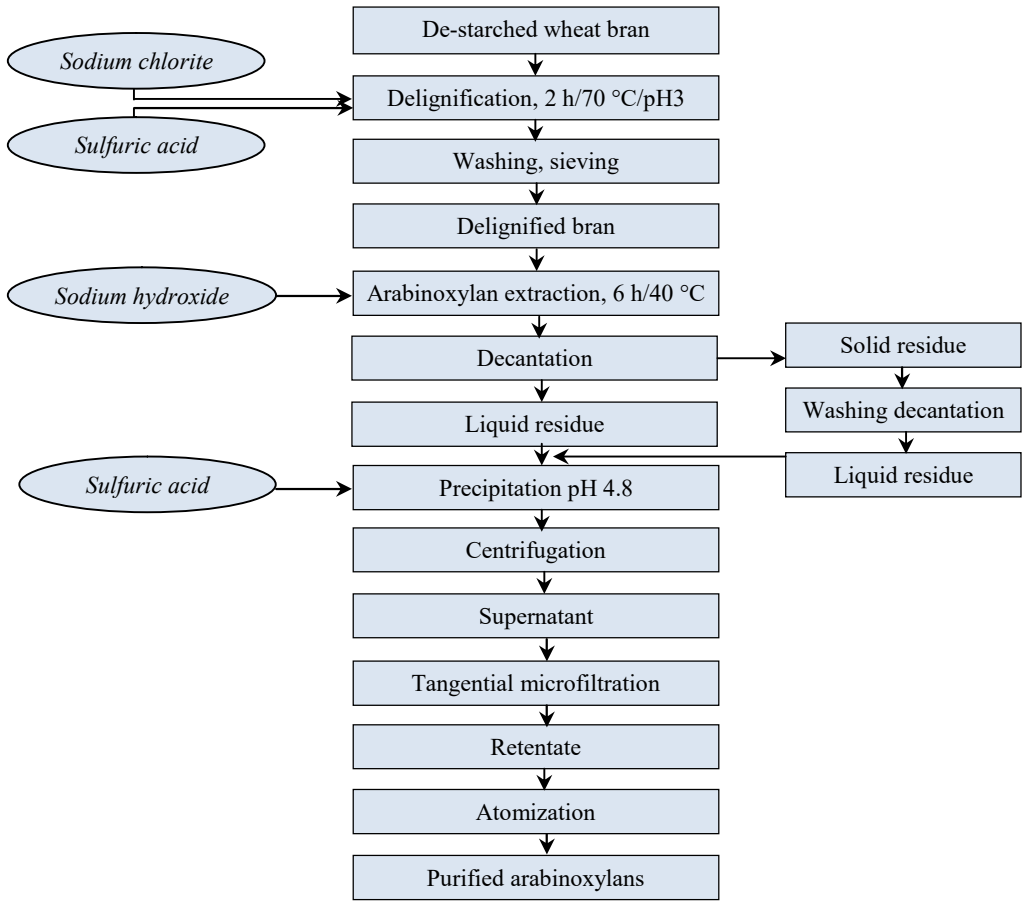

Fig. 3 – Flow scheme for extraction of AX from wheat bran.

Table 2

Composition, extractability of arabinoxylans, and arabinose-to-xylose ratio of whole rye and enriched rye-milling fractions

	Total dietary fiber, %	Cellulose, %	β-Glucans, %	Lignin, %	Total AX, %	Water-extractable AX, %	Ara/Xyl (WE)	Ara/Xyl (WUE)[b]	Ferulic add, mg/100 g
Whole Rye	15.1	1.3	1.5	1.5	9.0	41	0.64	0.63	93
Pericarp/testa fraction	73.3	13.6	0.46	11.0	39.5	14	1.17	1.02	659
Aleurone fraction	28.3	2.0	3.3	3.9	17.1	27	0.57	0.35	193
Endosperm fraction	6.5	0.4	0.75	0.2	4.2	70	0.71	0.83	17

Note: AX = arabinoxylans; WE = water-extractable arabinoxylans; WUE = water-unextractable arabinoxylans.

has an important effect on the capacity of the xylan chain to form cooperative intramolecular hydrogen bonds, and hence on its conformation, compared with cellulose. That is why, xylans form twisted threefold ribbon-like strands that are more flexible than the rigid twofold helices of cellulose [18]. The content of the arabinosyl substituents along the xylan backbone is closely related to the solubility of arabinoxylans.

The concentration of arabinoxylans is strongly influenced on the apparent viscosity of their aqueous solutions. The apparent viscosity increases with the polymer concentration and depend on the rate of shear at which the viscosity measurements are taken. With the increasing shear rates, arabinoxylans display a shear thinning. An important determinant of the solution behavior of these polymers is the molecular size of arabinoxylans. The behavior of arabinoxylans in solutions and their viscosity-building properties are the main characteristics responsible for the functional properties of arabinoxylans in the human digestive tract. The molecular weight of AX is influenced by cultivation conditions and cereal processing technologies. Arabinoxylan solutions possess a unique capacity to form hydrogels in the presence of free radical-generating agents, such as peroxidase-H_2O_2, laccase, linoleic acid-lipoxygenase, ammonium persulfate, or ferric chloride [4]. Covalent cross-linking of arabinoxylan chains through dimerization of ferulic acid substituents is responsible for this unusual property of arabinoxylans. The central role of feruloyl groups in gelation of arabinoxylan solutions is evidenced by disappearance of ferulic acid residues with a simultaneous formation of ferulic acid dimers and trimers during the initial stage of the gelation process. Arabinoxylan gels have neutral taste and odor, very high water absorp-

tion capacity (up to 100 g of water per gram of dry polymer), and are not susceptible to changes in pH or electrolyte concentrations. These properties, together with the macroporous texture of gels (mesh sizes varying from 200 to 400 nm) and the dietary fiber nature of AX, give them potential to be used as matrices with controlled releases of active agents in the food, cosmetic, and pharmaceutical industries [7].

Arabinoxylans play an important role in end-use quality of flour, mainly through their interaction with water and aptitude to cross link other arabinoxylan molecules and proteins [18]. The functional properties of arabinoxylan are strongly associated with their molecular weights and degrees of branching [19]. The addition of AX in quantity 0.5 % in dough increase volume of bread and improve texture. Water-soluble arabinoxylans are believed to increase the viscosity of the dough aqueous phase, and therefore to have a positive effect on the dough structure and its stability, especially during the early baking processes, when a relatively high pressure is generated inside the gas cells. Water-insoluble arabinoxylans that are present in dough as discrete cell wall fragments can form physical barriers for the gluten network during dough development. The resulting gluten has lower extensibility and a lower rate of aggregation, and therefore a different network structure. AX have a negative effect on gluten strength in addition in amount 1 % [18]. Another functional property of arabinoxylans may be associated with their role in bread staling. Bread staling is a complex phenomenon involving loss of aroma, deterioration of crust characteristics, and increase in crumb firmness.

Arabinoxylans as part of dietary fiber have many potential physiological effects along the entire human gastrointestinal tract. AX and various XOS proliferate of potentially health-promoting bacteria (probiotics).

Xylooligosaccharide preparations (containing mainly β-(1→4)-xylooligosaccharides ranging in size from DP 2 to DP 5) support the proliferation of many *Bifidobacterium* and *Bacteroides* species, *Lactobacillus brevis,* but are not fermented by *Escherichia coli,* enterococci, *Clostridium* sp., and the majority of *Lactobacillus* sp. Various arabino-xylooligosaccharides with DPs of 5 to 10 containing mainly doubly branched xylose residues and completely fermented by *Bifidobacterium adolescentis, Bifidobacterium longum,* and *Bacteroides vulgatus.* Intact arabinoxylans from wheat were fermented by *Bifidobacterium longum* and *Bacteroides ovatus* [20].

Consumption of AX 2–10 g/day reduces of 0.045 mmol/L total cholesterol/gram soluble fiber and have a significant reduction in blood glucose, fructosamine, and insulin concentrations . AX included in the fibers are prized for their potential to prevent colon cancer. Arabinoxylans are readily fermented by the colonic microflora to short chain fatty acids (SCFA). SCFA serve as an energy source for intestinal epithelial cells and reduce the pH in the intestine, thereby preventing the overgrowth of pathogenic bacteria. The presence of ferulic acid covalently bound to these polymers can also be associated with the beneficial role of arabinoxylans in the human diet. Ferulic acid plays a role as an antioxidant, inhibiting lipid peroxidation and low-density lipoprotein (LDL) oxidation and scavenging oxygen radicals, has strong anti-inflamatory properties, inhibits chemically induced carcinogenesis in rats [18].

The developments of various procedures for obtaining partially degraded arabinoxylans from agricultural by-products were prompted by advances in the area of prebiotic activity of oligosaccharides. It is known that xylooligosaccharides improve the intestinal function and have prebiotic properties by enhancing the growth of healthy *Bifidobacteria,* while suppressing the growth of *Clostridium* and having bacteriostatic effects against *Vibrio anguillarum.* The obtaining of xylooligosaccharides from arabinoxylans can be carried out by direct enzymatic or acid conversion of by-products or by hydrolysis of isolated polysaccharides [20, 21].

Conclusion

The development of new functional ingredients has the advantage that food manufacturers can add extra value to products the consumer is already familiar with. By either developing new and innovative products or just reformulating existing ones, nutritional food ingredients enable manufacturers to meet and exceed the expectations of today's health-conscious consumer. Cereals not only have the ability to grow and deliver probiotic lactic acid bacteria to the human gut, but also contain potentially prebiotic compounds whose functionality should be explored.

AX are a considerable part in cereal grain plant tissues. The highest concentration in the grain is placed in the outer layer. They are bound by covalent and non-covalent crosslinks to other plant tissue polymers such as lignin, proteins and cellulose. AX improve food systems and affect human health. A possible way to reach technological benefits could be the modification of polysaccharides structures by use of water extraction, chemical or enzymatic hydrolyses. Also AX, obtained by enzymatic treatment, improve dough and bread characteristics.

Arabinoxylans are a rich source of oligomers (e. g. XOS) that can be obtained by enzymatic hydrolysis. These oligomers have the ability to grow and deliver probiotic lactic acid bacteria to the human gut, but also contain potentially prebiotic compounds whose functionality should be explored. Various arabinoxylooligosaccharides with DPs of 5 to 10 containing mainly doubly branched xylose residues and completely fermented by *Bifidobacterium* and *Lactic acid bacteria*. Thus, the use of arabinoxylans as a raw material for the production of prebiotic-oligosaccharides is a promising area for the development of functional products intended for the correction of intestinal microbiota.

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СОВРЕМЕННЫЕ ТЕНДЕНЦИИ И БУДУЩИЕ ПЕРСПЕКТИВЫ ИССЛЕДОВАНИЙ АРАБИНОКСИЛАНОВ ПРЕБИОТИКОВ: ОБЗОР

Аннотация

Развитие производства новых физиологически функциональных ингредиентов позволяет, как расширить ассортимент этих добавок, так и привлечь дополнительные нетрадиционные сырьевые источники. Пребиотики являются неперевариваемыми пищевыми ингредиентами, которые стимулируют рост пробиотических бактерий в желудочно-кишечном тракте. По химической природе большинство пребиотиков – это полимеры углеводной природы: пищевые волокона и неусваиваемые олигосахариды. Среди некрахмальных полисахаридов первостепенное значение имеют арабиноксиланы (АК), арабиногалактаны (АГ) и β-глюканы. Арабиноксиланы в основном содержатся в зерне злаков, таких как, пшеница, рожь, ячмень, овес, рис и сорго.

Данная статья представляет собой обзор литературы и собственных исследований авторов по химической структуры, биосинтезу, получению, физико-химическим и физиологическим свойствам АК. Структура и молекулярная масса АК являются основополагающими факторами определяющими их физико-химические, технологические и физиологические свойства. В статье подробно описан биосинтез АК в растительной ткани, позволяющий понять механизм образования сложной структуры этих полисахаридов. Основная часть АК зерновых содержится главным образом в клеточных стенках крахмального эндосперма и алейроновом слое, в отрубях и в шелухе некоторых злаков. Количественное распространение и структура АК в определенных слоях растительной ткани зависит от рода и вида сырья. Однако было установлено, что степень разветвления АК алейронового слоя ниже, чем АК отрубей. Молекулярная структура АК из пшеницы,

ржи и ячменя менее сложна, чем в рисе, сорго, просе и отрубей кукурузы, поскольку их боковые ветви содержат помимо остатков арабинозы небольшие количества ксилопиранозы, галактопиранозы и α-D-глюкуроновой кислоты или 4-О-метил-α-D-глюкуроновых остатков.

В обзоре проанализированы методы получения водорастворимых и нерастворимых в воде АК из разного сельскохозяйственного сырья. Водорастворимый АК экстрагируют при помощи высокотемпературной обработкой с последовательным удалением из сырья крахмала ферментативным путем. После экстракции горячей водой разделяют нерастворимые волокна и белковые фракции. Промытые нерастворимые волокна дополнительно обрабатывают раствором NaOH. Также описаны технологические свойства АК, полученные из разных злаков.

При ферментативном гидролизе АК образуются арабиноксилоолигосахариды (АКОС), состоящие из арабиноксилоолигосахаридов и ксилоолигосахаридов (КОС). Этот процесс лежит в основе производства пребиотических арабиноксилоолигосахаридов из зерновых культур и вторичных продуктов их переработки. В обзоре основное внимание уделяется перспективам использования арабиноксиланов в качестве сырья для получения олигосахаридов-пребиотиков.

Ключевые слова: *пребиотики, арабиноксиланы, злаковые, олигосахариды, ксилоолигосахариды, Lactic acid bacteria, Bifidobacteria.*

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