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MINI-REVIEW

An Overview of Non Starch Polysaccharide

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Abstract

Polysaccharides are macromolecules of monosaccharides linked by glycosidic bonds. Polysaccharides are widespread biopolymers, which quantitatively represent the most important group of nutrients in feed. These are major components of plant materials used in rations for monogastrics. Non-starch polysaccharides (NSP) contain ß-glucans, cellulose, pectin and hemicellulose. NSP consist of both soluble and insoluble fractions. Soluble NSP of cereals such as wheat, barley and rye increases intestinal viscosity there by interfere with the digestive processes and exert strong negative effects on net utilisation of energy. NSP cannot be degraded by endogeneous enzymes and therefore reach the colon almost indigested. Insoluble NSP make up the bulk in the diets. NSP are known to posses anti-nutritional properties by either encapsulating nutrients and/or depressing overall nutrient digestibility through gastro-intestinal modifications.

Key words: Polysaccharides, Starch, Digestibility.

1. Introduction

Non starch polysaccharides (NSPs) are carbohydrate fractions excluding starch and free sugars. These are polymeric carbohydrates differing in composition and structure from amylase and amylopectin (Chesson, 2001). They are the plant structural analogues of the skeletal system of animal kingdom. NSPs are α-linked polymers of pentoses and hexoses having high molecular weight ranging from 8000 to a million. NSPs constitute the major fraction of cell wall polysaccharides and are closely associated with other polysaccharide or non-carbohydrate material such as protein and lignin.

Under NSP cellulose, hemicellulose, pectins and oligosaccharide (alpha-galactosidase *etc*.) are included. The dietary fibre is mainly formed by NSPs and lignin. Chemically, NSP consists of macromolecular polymers of monosaccharides joined by a specific type of linkage called glycosidic bond formed between hemiacetal group of one sugar and the hydroxyl group of another (Hesselman, 1989). NSPs are present both intra and extra-cellularly but the majority originate from the cell wall. The endogenous enzymes can't hydrolyse it. In cereal grains the NSP present are mostly xylans, arabinoxylans (pentosans), beta-glucan and cellulose. The stem and leaves contain small amount of pectic polysaccharides. In the leguminous plants cellulose and xylans are present only in the hull and husk portion. The cotyledon of legumes contains pectic polysaccharide. The NSP content of plants varies not only with the plant species but also between genotype and cultivar of the same species. Furthermore the agronomic cultivation conditions such as environmental factors prior to harvest and storage conditions after harvest can influence NSP content.

2. Classification of NSP

2.1 On the Basis of Solubility (Fig 1)

- Cellulose –Insoluble in water, alkali or dilute acids.
- Non-cellulosic polymers-Arabinoxylans mixed linked beta glucans, mannans, galactans, xyloglucan, fructan. These are partially soluble in water.
- Pectic polysaccharides-Poly galactouronic acids which may be substituted with arabinan, galactan and arabinogalactan. These are partially soluble in water. (Choact, 2002)

2.2 On the Basis of Linkage

- Water soluble or partially water soluble: Beta 1, 4 glycosidic linkage backbones with beta 1, 3 linkages.

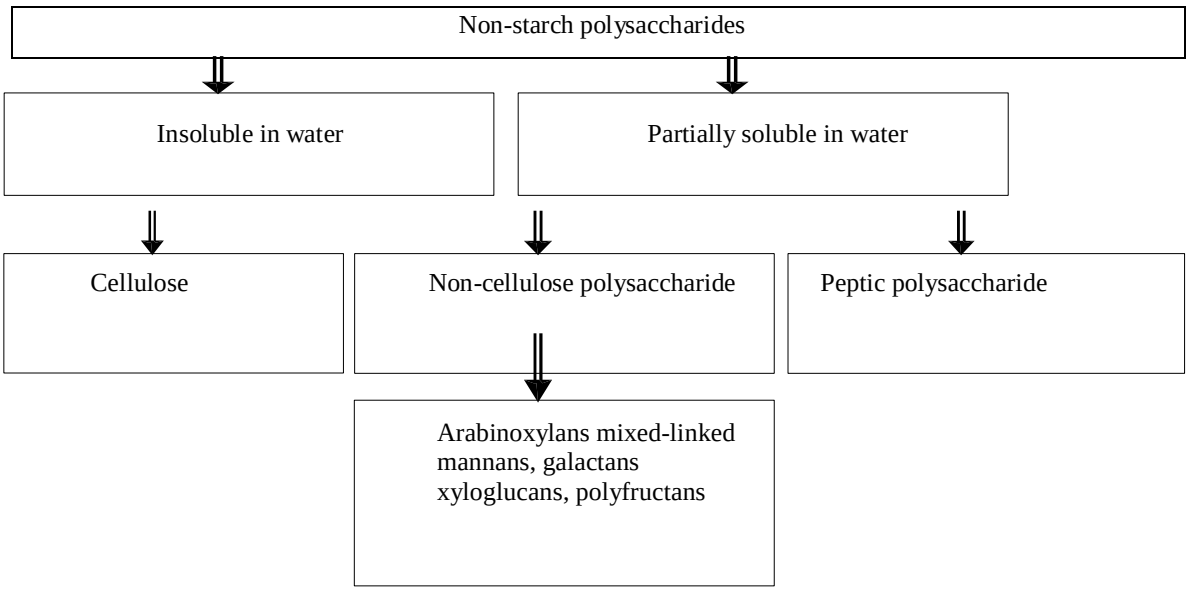

Fig 1: Classification of NSPs

- Water insoluble: Long sequence of beta 1,4 glycosidic unit.

3. Common NSPs of Plant Cell Walls

Though commonly called NSPs, the plant cell wall polysaccharides include a wide range of chemically distinct compounds in different combinations and proportions characteristic to and variable between different species of plants. Some of the common NSPs present in the plant cell walls, broadly classified into Cellulosic, Hemicellulosic, Pectic and/or Galactosidic substances.

3.1 Cellulose

Made up of linear unbranched chain of (1-4) linked D-glucose molecules. Cellulose is believed to be identical in chemical composition regardless of sources. Cellulose is insoluble in water, alkalis and dilute acids.

3.2 Hemicelluloses

Hemicelluloses are low molecular weight miscellaneous non cellulosic polysaccharides forming the major fraction of NSPs. It is partially soluble in water. They are found most often as heteropolymers and less commonly as homopolymers of monosaccharides and mainly include D-xylose, D-mannose, D-galactose, L-Arabinose, D-glucuronic acid, D-glucose *etc*. The commonly occurring hemicelluloses include:

3.3.1 Pentosans

Pentosans are composed predominantly of two pentoses, arabinose and xylose. Main chain of the pentosans is made of (1-4) linked xylopyranose residues. Side chain made of (1-3) linked arabinofuranosyl residues which, in turn, are attached to C-3 position of the xylan main chain. The major substitutes are single arabinose residues, although in many instances hexoses and hexuronic acids are present in minor proportions.

3.3.2 D-glucans

It consists of linear chain of glucopyranosyl residues (glucose units) joined by both (1-3) and (1-4) linkages.

3.3.3 Mannans

Glucomannans have been found as a minor component of cereal grains. The glucomannans are comprised of (1-4) - linked glucose and mannose units.

3.3.4 Arabinans and Galactans

The arabinans are polymers of (1-5)- -L-arabinose residues branched through 02, 03 or both positions, whereas the galactans are polymers of (1-4) - D-galactose residues.

3.3.5 Galactomannan

Made of (1-4) linked mannan backbone to which D-galactose side chains are attached at C-6 positions.

3.3.6 Xyloglucans

The structure of xyloglucan is made of (1-4) linked D-xylopyronosyl(xylose) residues are attached at C-6 positions

3.4 Pectic Polysaccharides

The term pectic polysaccharides refer to galacturonans and rhamnogalacturonans.

3.4.1 Polygalacturonans

Main chain is made of (1-4) linked D-galacturonic acid and side chain consists of either (1-3) linked D-xylose, (1-6) linked D-galactose or (1-4) linked -arabinose and less frequently with –fructose.

3.4.2 Rhamnogalacturonans

Similar to polygalacturnonan except that the main chain in addition to D- galacturonic acid, contains (1-2) linked rhamnose residues resulting in a bent macromolecule.

3.4.3 Oligosaccharides (α-galactosides)

Successive addition of α-galactosyl residues to sucrose primer leads to formation of raffinose, stachyose and verbascose *etc*.

4. Properties of NSPs

Many NSPs dissolved in water result in viscous solutions. NSPs increase viscosity by directly interacting with the water molecule. At higher concentration, the molecules of the NSPs interact themselves and become entangled in a network further increasing the viscosity (Simon, 1998). Because of the formation of network with water, the viscosities and water holding capacities of soluble NSPs are relatively high compared to insoluble NSPs.

The degree of solubility is directly proportional to the degree of branching of the NSPs molecule (Annison, 1993). In arabinoxylan, side chain with arabinose is soluble and in pectins, side chain with arabinose and xylose are soluble whereas in both, the main chain is insoluble. Among Beta-glucans those with (1-3) linkages are soluble and those Beta (1-4) linkages are insoluble whereas cellulose is completely insoluble. Some NSPs such as pectins may have high charge density at a given pH value because of presence of acidic groups. The carboxyl groups can bind to cations influencing the mineral absorption in intestines.

5. NSP Content of Various Feed Ingredients

The NSP contents of different feed ingredients as per various reports are given in Table 1. The NSP in cereal grains are composed predominantly of arabinoxylans (pentosans), glucans and cellulose (Table 2). NSP content of rice, jowar and maize is comparatively low. Cereal by-products, which are obtained after separating away the starchy portion, have very high values of NSPs.

6. Methods Used For Estimation of NSPs

Different methods used for estimation of NSPs are:

- Gravimetric method
- Colorimetry method
- Gas chromatography
- Enzymatic method

6.1 Gravimetric Methods

Gravimetric methods measure the insoluble residue after chemical or enzymatic solubilisation of non-fibre constituents. Gravimetric methods are easy to handle and do not require any special equipments.

6.1.1 Detergent Method

This method was first suggested by Van Soest (1963). It includes treating the feed with a detergent and either acid (acid detergent fibre, ADF) or neutral buffered solution (Neutral detergent fibre, NDF). Ideally, ADF determines cellulose and lignin and NDF method measures cellulose, hemicellulose and lignin, solubilises protein efficiently and fat to a limited extent.

NDF - ADF = hemicelluloses

6.1.2 Crude Fibre Method

It involves sequential extraction with dilute acid and alkali and isolation of the insoluble residue by filtration (Lange, 2000).

6.2 Colorimetric Methods

Carbohydrates undergo condensation reaction with strong acids like anthrone, orcinol and carbazole, which are relatively specific for hexoses, pentoses and uronic acid, respectively. Due to this reaction colour substances is produced that can be measured spectrophotometrically.

6.3 Chromatographic Method

Various chromatographic methods are used for estimations of NSPs. These are:

Table 1: NSP contents of some cereals on % DM basis (Irish and Balnave, 1993)

Cereal		Arabinoxylan	ß-Glucan	Cellulose	Total
Wheat	Soluble	1.8	0.4	2	2.4
	Insoluble	6.3	0.4	-	9.0
Barley	Soluble	0.8	3.6	3.9	4.5
	Insoluble	7.1	0.7	-	12.2
Rye	Soluble	3.4	0.9	1.5	4.6
	Insoluble	5.5	1.1	-	8.6
Triticale	Soluble	1.3	0.2	2.5	1.7
	Insoluble	9.5	1.5	-	14.6
Sorghum	Soluble	0.1	0.1	2.2	0.2
	Insoluble	2.0	0.1	-	4.6
Maize	Soluble	0.1	-	2.0	0.1
	Insoluble	5.1	-	-	8.0
Rice	Soluble	T	0.1	0.3	0.3
	Insoluble	0.2	-	-	0.5
Soya bean	Soluble	2.7	-	4.4	2.7
	Insoluble	16.5	-	-	16.5

Table 2: NSPs present in feed and fodders

Ingredient	NSP component	Reference
Wheat	Arabinoxylan	Mares and Stone (1973)
Rye	Arabinoxylan	Henry (1987)
Tritacale	Arabinoxylan	Henry (1987)
Maize	Arabinoxylan	Annison (1991)
Oats	Mixed linked glucans	Henry (1987)
Barely	Mixed linked glucans	Fincher (1975)
Soya bean	Galacturonans, arabinans with galactose	Annison (1991)
Lupine	Rhamnogalactouronan with arabinose and galactose	Annison (1991)
Rapeseed	Arabinogalacton, uronan	Mares and Stone (1973)

6.3.1 Thin Layer Chromatography

It is used for separation of individual sugars like monosaccharides or oligosaccharides. It is most commonly used for raffinose series of oligosaccharides viz, raffinose, stachyose, verbascose, *etc*. The ethanol extract containing mixture of sugars and spotted on the TLC plate (cellulose coated), developed using suitable solvents, individual sugars are identified and recovered and then estimated spectrophotometrically (Roy *et al.*, 2002).

6.3.2 Gas Liquid Chromatography (GLC)

The monomeric constituents of the NSPs are liberated by acid hydrolysis. GLC gives more accurate results than other methods. High performance liquid chromatography (HPLC) is an alternate to GLC method to estimate NSPs.

6.3.3 Enzymatic Methods

Amylolytic and proteolytic enzymes are used for starch and protein solubilisation. It measures soluble fibre and insoluble fibre separately (Beoford and Campbell, 1991).

7. Role of NSPs in Animal Health

The insoluble NSP make up the bulk of the total fibre in diets. It full fills the satiety of the animals. Small quantity is beneficial in promoting evacuation of gut contents/ defecation and maintaining normal gut health. Very high concentration of dietary fiber shortens residence time of digesta leading to reduced digestion and absorption of feed nutrients. Soluble NSPs acts as anti-nutritive substance in the body. It undergoes rapid fermentation in intestine and act as source of energy for anaerobic microbes. It helps to

propagate harmful pathogen like *Clostridium perfringens* which causes various diseases in animals and poultry.

NSP is associated with an increase in digesta viscosity in broiler chicken (Beoford *et al.,* 1993). The viscous properly impairs the diffusion and connective transport of lipase, oil and bile salt micelles within gastro-intestinal contents. (Smits and Annison, 1996). Dietary fibre increases secretion of mucous (Chesson *et al.,* 2001). It increases the resistance for transport of nutrients through the epithelial surface by increasing the thickness of mucous layer and changing physiochemical property of mucus. Viscous property of NSP delays digestion and absorption due to encapsulation of nutrients (Beoford, 1991).

Choact *et al*. (1996) recently demonstrated that diets rich insoluble NSP markedly elevated fermentation in the small intestine. NSP does not only interfere with digestive processes, but also have strong negative effects on availability of energy and nutrients to the animals. Simon (1998) reported that diets high in insoluble NSP is very effective in preventing the onset of cannibalism in laying hen. It is due to bulky nature of fibre and its subsequent effect on digesta transit rate.

8. Improvement of NSPs Utilization

NSP utilization can be improved by the following methods:

- Water treatment
- Antibiotics
- Enzyme supplement
- Milling
- Gamma radiation

8. 1 Water Treatment

Water soluble NSP are removed. Degree of improvement depends upon concentration of water soluble NSP in cereals.

8. 2 Antibiotic Supplement

On high NSPs diet, unwanted intestinal microbes will start proliferating, chiefly *Clostridium perfringens*. Antibiotic supplement will check their growth and thereby alleviate the undesirable effect of NSPs. Antibiotics also enhance the absorption of nutrient as they also prevent the thickening of mucosa of intestine.

8.3 Enzymes Supplementation

Supplementation of lipase and proteolytic enzymes increases the utilisation of NSPs in animal body. Enzyme supplementation strategy should be followed based on age and level of NSPs in feed.

Mode of enzyme action: It decreases the viscosity of the rumen mass and thus enhances the nutritive value. There is improvement in the energy value of cereal diets due to improvement in nutrients (starch, protein, fat) digestibility. Properties of feed enzymes:

- It should not be digested by host enzymes.
- It should have a wide range of pH activity (2.00-8.00).
- It should be able to bear temperature (15-45^{o} celsius).
- It should be economical.

8. 4 Milling

The coarse fiber has high water holding capacity. Milling decreases the particle size as well as the water holding capacity of fiber thus promotes fermentation by micro organisms.

8.5 Irradiation

Irradiation of rye lowers the degree of polymerization of pentosan fraction and reduces invitro viscosity.

9. Conclusion

Although indigestible NSPs are available in market in competitive prices, it is not added to the diet in large amounts. However breakdown of complex polysaccharide can be done by addition of NSP degrading enzymes. But it is difficult to select suitable enzyme mixtures as feed additive in such diets due to lack of the knowledge of the nutritive value of the enzymes and the idea of presence of antinutritive factors. Knowledge of the chemical structure of NSP has permitted the development of enzyme technology to overcome the adverse effects.

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