A REVIEW

Microbial xylanase : Its important role in various industries

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SUMMARY

Xylanase enzymes, hydrolyze xylan subtrates and play a major role in industries.Xylanases are most distributed enzymes in bacteria, fungi and plants. For commercial applications,xylanases should ideally be produced quickly and in large quantities from simple and inexpensive substrates. Natural xylan sources such as agricultural and forestry wastes, paper industry wastes and various fruit wastes are potential raw materials for xylanase production. Among these, food industry wastes contain high amount of xylan,as its one of the main polymers in the plant cell wall. These wastes are potential raw material for xylanase production and as xylanases have a wide range of application, in fruit juice extraction, separation of oil and grease by crude xylanase paper and pulp industry, bread making, degumming of plant fibers and also acts as detergents, nutrition for pigs and chickens and recycling of waste cotton. The present review mainly sates the xylan structure, biodegradation of xylan,xylanase and applications of xylanase in various industries.

Key words : Xylanase, Structure of xylan, Xylanase applications.

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Xylan is hemicellulose and the second most abundant natural polysaccharide (Collins *et al.,* 2005). It is present in the cell wall and in the middle lamella of plant cells. (Polizeli *et al.,* 2005). This term covers a range of non-cellulose polysaccharides composed in various proportions of monosaccharide units such as D-xylose, D-mannose, D-glucose, L-arabinose, D-galactose, D-glucuronic acid and D-galactouronic acid. In nature, wood hemi celluloses hardly ever consist of just one type of sugar. Usually they are complex structure made of more than one polymer, the most common being glucuronoxylans, arabino glucuronoxylans, glucomannans, arabinogalactans and galacto glucomannans (Haltrich *et al.,* 1996; Kulkarni *et al.,*1999; Sunna and Antrainckian, 1997). It is a polymer therefore the complete degradation of natural xylan requires a concerted action of several enzymes. Endo- 1,4-β-Xylanases (EC-3.2.1.8) are glyloside hydrolases that cataly 2C a random hydrolysis of the internal β-1,4-glycosidic linkages of xylan (Collins *et al.,* 2005). Xylanases produced from various microorganisms, such as bacteria, fungi, protozoans and germinating seeds. This focuses the application of xylanase in paper and pulp industry, juice processing, bread making, detergent and in recycling of waste cotton.

Enzymatic action on xylanin the agricultural residues:

Xylan:

Xylan is the most abundant non-cellulosic polysaccharide present in both hard woods and annual plants and accounts for 20-35% of the total dry weight in tropical plant biomass. In temperate soft woods, xylans are less abundant and comprise about 8% of the total dry weight. Xylan is found mainly in the secondary cell wall and is considered to be forming an interphase between lignin and other polysaccharide.Xylans are linear homopolymers that contain D-xylose monomers linked through β-1,4-glycosyl bonds (Srinivasan and Rele, 1999).

Structure of xylan:

In nature, the xylans are partially substituted by acetyl 4-0-methyl –D-glucoenosyl and 1-arabinofuranosyl residues forming complex heterogeneous and polydispersed, polymers. The structure of xylan found in cell walls of plants can differ greatly depending on their origin but they always contain a β-1,4-linked D-xylose back bone (Ebringerova and Heinze,2000).

Arabinose is connected to the backbone of xylan via an ∝-1,2 or 1,3 linkage either as single residue or as short side chains.Glucuronic acid and its 4-0-methyl ether are attached to the xylan backbone via an μ-1,2-linkage whereas aromatic feruloyl and P-coumaryl

residues have so far been found attached only to 0-5 of terminal arabinose residues (Saulnier *et al.,*1995).As a consequence of all these feature, the xylans form a very heterogenous groups of polysaccharide (Huisman *et al.,*2000).

Biodegradation of xylan:

A complete and efficient bio-degradation of xylan depends mainly on two types of enzymes: 1.Endo-β-1,4-xylanase which hydrolyze of the xylanopyranose of the central chain and β- Xylosidase which hydrolyze other xylo oligosaccharides resulting from the action of endoxylanase. Other enzymes used for biodegradation were acetyl xylanoasterases, glucuronidase,L-arabinofuranosidase (Saha and Bothast,1999).The xylanases commonly act on the xylans like arabinoxylan and,arabino-4-O-methyl,D-glucuronoxylan.Due to its complex structure, the degradation of xylan requires the synergistic action of several hydrolytic enzymes for efficient and complete breakdown.

Xylanase :

Endo-1,4-β-Xylanase (1,4- β -D -Xylan Xylanohydrolase; Ec.3.2.1.8) cleaves the glycosidic bonds in the xylan back bone, bringing about a reduction in the degree of polymerization of the substrate. Xylan is not attacked randomly but the bonds selected for hydrolysis depend on the nature of the substrate molecule. Initially the hydrolysis products are β -D-Xylopyranosyl oligomers, but at a later stage small molecules such as mono, di and trisaccharides of β-D-xylopyranosyl may be produced. The hydrolysis of Xylan by an endo xylanase may be written as follows:

$$H(C_5H_8O_4)n\ OH+H_2O$$
$$H(C_5H_8O_4)n\text{-}p\ \ OH+H(C_5H_2O_4)_p\ OH$$

This equation shows the stochiometry of a single hydrolytic event in a xylan molecule; such a reaction may occur at many points in the chain (Polizeli *et al*., 2005)

Xylanase produced by some microorganisms applications of xylanases:

Xylanases produced by microorganisms have attracted a great deal of attention during the past few decades because of their potential biotechnological applications in various industries.

Xylanases from different organisms have been evaluated for their interaction with various kinds of pulps.The application of the xylanase as a prebleaching agent will reduce the pollution from paper pulp factories.The xylanase dose for the biobleaching of eucalyptus kraft pulp at 50^0C was optimized as 1.8 Ug-1 moisture free pulps.The bio bleaching efficiency of xylanase treatment on eucalyptus pulp was maximum offer 4h with a reduction in kappa number by 25% and release of reducing sugars increased 10 fold (Gupta *et al.,* 2000).When the kraft pulp was pretreated with xylanase, the xylose sugar was released from the xylan layer of hemicelluloses resulted in the high free sugar content in the pulp sample. Since xylan is a part of hemicelluloses which is sandwiched between the lignin and cellulose layers. When xylan was degraded by the xylanase, in addition to xylose, it also caused the release of lignin and phenolic compounds from the pulp fibres.

The enzymatic treatment and subsequent alkalinization allowed part of the residual lignin to be extracted from pulp. Increase in the enzymatic treatment assisted a more complete extraction of the residual lignin. The brightness of hardwood kraft pulp samples after washing increased to 53% (Aleksandrova *et al*., 2000).The extent of chlorine dioxide reduction during bleaching depended on the pulp type and enzyme used. In bagasse pulp, the chloride dioxide consumption was reduced (Madhala *et al*., 2001). The brightness improvements achieved by xylanase pretreatment could be translated into savings of chlorine dioxide.The xylanase pretreatment reduced the kappa number and then release of reducing sugars.

The crude xylanase preparation of *Thermomyces lanuginosus* was able to decrease the kappa number of Soda-aq pulp by up to 14% where as the commercial enzyme lowered the kappa number of bagasse pulp by up to 2%.

Biotechnological potentials of xylan and xylanases:

The applications of xylan and xylanases have been of particular interest to biotechnologists.The xylan releases the furfural and xylitol as the major end products. Furfural production is derived mainly from agricultural residues.Where as xylitol is obtained from wood residues.In the pharmaceutical industry xylan is found suitable as a agent for tableting.The xylan hydrolysis products can be subsequently converted to liquid fuel, single cell proteins, solvents and artificial low calorie sweeteners (Wong and Saddler, 1992).

Applications of xylanases:

Pulp and paper industry:

Environmental regulations have put a restriction on the usage of chlorine in the bleaching process in the paper and pulp industry, especially in western European countries

and in north America (Chauvt *et al.*,1987). Xylanase promotes bleaching by the hydrolysis of relocated reprecipitated xylan on the surface of the pulp fibers allowing for better chemical penetration and thus improving lignin extractability (Kantelinen *et al.*,1993). The reprecipitated xylan forms a barrier for the extraction of lignin, in both hard wood and soft wood pulps thus treatment with xylanase makes the pulp more permeable for the subsequent chemical extraction of residual brown lignin and lignin carbohydrate molecules from the fibers (Medeiros *et al.*,2003). Apart from the wood pulp bleaching xylanases are applied in the bleaching of various pulps such as wheat straw pulp.In the waste paper recycling the xylanase plays a key role in bleaching (Savitha *et al.*,2007). Scanning electron microscope studies of xylanase-pretreated pulps revealed an increase in the porosity of pulp fibre aiding in pulp accessibility to bleaching chemicals. Xylanases are important in food and feed technologies, since their target enzymes are often applied industrially. Indeed, endoxylanases are used in many food and feed applications to degrade or modify the arabinoxylan population in order to improve processing and or/ end use quality of cereal products.

Waste cotton recycling:

The serious waste water pollution caused by textile finishing has oriented recent research towards application of enzymes in wet processes. The several non-celluloytic enzymes are used effectively in the cleaning procedure of cotton. In the traditional scouring process-which is energy and chemical intensive-concentrated sodium hydroxide solution and additional hydrogen peroxide and/ or sodium hypo chlorite solutions are applied for removing the impurities from raw cotton. The enzymatic treatment for cotton provides an environmentally friendly alternative (Buchert *et al.*, 1998).The rates of degradation of seed-coat fragments and that of desized cotton fabric were compared. Weight loss and lightness of the substrates were also measured often the enzymatic and the subsequent alkaline treatments (Csiszar *et al.*, 2001).The addition of the EDTA to the enzyme solution resulted in higher weight losses of the cotton fabric. The small weight loss falines caused by the enzymes showed that the non cellulosic constituents of the cuticle were removed without significant cotton cellulose degradation. The consecutive enzymatic treatment and alkaline scowing, weight loses were around 80% (Csiszar *et al.*, 2001). The enzymes may be used as appropriate dosage and conditions for modification of the cotton fibre, without a remarkable harmful effect.

Xylanase in wire cut cookies:

The use of xylanase breaks down insoluble components of the cell walls resulted solublization the component (Hilhorst, 1999). The effect of xylanase enzyme addition on the physical and sensor, properties of cookies when fibres from different sources have been added to the formulation. The use of xylanase enzyme on the level of 0.4% based on the wheat flour used, produced with softer texture and reduced separations (Uysal *et al.*, 2007).

Acts as detergents:

For an enzyme to be used as a detergent additive, it should be stable to such detergent components as surfactants, builders bleaching agents, bleach activators and other formulation chemicals. Xylanases are used along with proteases in detergent formulations to solublise stubborn stains of plant origin. Xylanases from alkaliphic *Bacillus* sp. NCL (Suh *et al*.,2004) are not only compatible with a wide variety of commercial detergents of different formulae but can also be used as a detergent additive (Kumar *et al.,* 2004).

Clarification of juices:

The maximum juice yield was attained when the fruit pulps were treated with the enzyme mixture that contained xylanases (2.0 Ug-1), increased the volume of fruit juices of pulp. (Kumar *et al.,* 2004). The additions of enzymes allows more specific degradation that is necessary to give smooth texture to juice, and at the same time preserves coloured vitamins (Grasin and Fauquenbergue, 1996).

Provide more nutrition for pigs and chickens:

The xylanase supplementation at different levels increases the nutrient digestibility and performance of the weaned pig (Yin *et al.,* 2001). Addition of the enzyme to the diet did not affect the total faecal VFA and lactate concentrations. However, there were some changes to VFA molar proportions with addition of the enzymes, with the propionate and iso butyurate molor proportions decreasing and increasing, respectively. The addition of enzymes also improved faecal score as the smaller NSP fragments were likely to have less capacity to hold water as they passed through the intestines, reducing the osmotic load (Choct, 1999).

Xylanase supplementation increased feed intake in ground wheat diets, but reduced it in whole wheat diets (Wu and Ravindran, 2004). Xylanase increased the apparent faecal digestibility in coefficients of crude protein, crude fat, crude fibre, organic matter, nitrogen free extract and non starch polysaccharides. The increased apparent

faecal digestibility coefficients resulted in a higher energy value of the cereal based diet supplemented with xylanase (Sterk *et al.,* 2007). Crude xylanase from *Aspergillus niger* contained not only xylanase but also other carbohydrases, proteases, and phytase activities that were more specific to various feed ingredients.Eg: Cassava meal, rice bran, soybean meal, and maize. *Aspergillus niger* crude xylanase shows the potential feed enzyme supplement in pig lets. (Tapingkae *et al.,* 2008).

Separations of oil and grease by crude xylanase:

The influence of enzyme xylanase on the oil separation was due to the fact that oil in the effluent was of both free and attached forms. In the latter case, microscopic observation showed that the oil droplets were attached to the fine residual fibers. During incubation the hemicellulose content of the residual fibre was degraded by the enzyme. The degradation of xylan in the fibre was reported not to exceed 20% due to the limitation of the enzyme in penetrating the fibers to hydrolyze the xylan (Wong *et al*., 1996).

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