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Properties of sugar beet pulp pectin: A systemic review

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Abstract : Sugar beet pulp, a major by-product of the sugar industry, is a common feed component in cattle diets that is preserved on-farm as silage. Sugar-beet (*Beta vulgaris* L.) pectins can be obtained from sugar-beet pulp, a residue of the sugar processing industry. Compared to other pectins obtained from other sources, like citrus, apple and sunflower pectins, sugar-beet pectins have the advantage that the raw material is already dried and does not depend on stationality. Sugar-beet pulp is sold as animal feed at very low prices and is readily available for revalorization. Sugar beet pectins have however poor gelling properties under the usual conditions, which have been ascribed to a relatively low molar mass, high degree of acetylation (DA) or a high amount of side chains. The presence of ferulic acid ester-linked to the arabinose and galactose residues of the side chains can, however, be used for chemical cross-linking of pectins, leading to gel formation. Sugar-beet pectins could be used as an efficient biosorbent for the treatment and recovery of Cu, Pb and Cd from wastewater.
Key words: Sugar beet, Pectin, Ethanol, D-galactose.

1. Introduction

Sugar beet (Beta vulgaris) pulp (SBP), a by-product of the sugar-refining industry, is mainly used as a feed formulation, with few other commercial uses. Moreover, the drying process requires high energy and often presents an environmental problem. Therefore, numerous attempts have been made to utilise this waste as a biosorbent for the removal of heavy metal ions[1], a source of pectins[2], feruloylated oligosaccharides[3] dietary fibres[4], and biofuels[5]. Specifically, a focus has been placed on pectin which exhibits superior emulsifying properties compared with commercial pectins[6].

Pectin, extracted from cell walls in most plants, is an anionic polysaccharide, which consists mostly of polymers rich in D-galacturonic acid (GalA) and often contains significant amounts of L-rhamnose (Rha), D-arabinose (Ara) and D-galactose (Gal) as well as 13 other monosaccharides[7]. In the industry, pectin is obtained from apple pomace and citrus peels chemically using conventional acid extraction, with strong acids such as sulphuric acid[8] and hydrochloric acid[9]. This generally results in degradation of the arabinan side-chains and therefore in a loss of feruloyl groups which are the key factors in cross-linking pectins[10].

Pectic substances are important polysaccharides of the cell walls of higher plants. They mainly consist of a back-bone of (1→4)- linked partly methylesterified α-D-galac-turonic acid units. This linear chain may be interrupted by (1→2)-linked α-L-rhamnopyranosy units bearing some side chains mainly composed of galactose and arabinose residues[11]. Pectins form gels certain conditions and this property is used in jams, jellies and marmalade, confection-neries and acid mild products[12].

Most of the pectins present in the sugar-beet pulp are high methoxyl and have more than 50% of methoxylated residues. They gel at low pH values and in the presence of a high concentration of soluble solids.

The resulting gels dissolve quickly in water and have a soft consistency and therefore have no application in the biosorption of metals or in the immobilization of biomass. Lowmethoxyl pectins have less than 50% of methoxylated residues and can be obtained from high-methoxyl pectins by demethylation. These pectins are sensitive to gelation with divalent cations such as calcium according to the "egg-box model" proposed by Rees but methoxyl groups are an impediment for the formation of the calcium bridges[13]. Their gels are stable in aqueous solutions and can be used in similar applications like those of alginate including biomass immobilization and heavy and preciousmetal biosorption, among others[14].

Demethylation occurs at low temperatures and in an alkaline media through a base-hydrolysis of the esther groups (saponification)[15,16]. At neutral or alkaline pH values pectin degradation takes place by the β-elimination of the glycosidic bond that is adjacent to the esterified units of the galacturonic acid. The degradation increases with temperature and is parallel to the demethylation process. Different types of pectin demethylation methods can be used: acid, alkali, ammonia and enzyme treatments[16].

Harel et al.[14] proposed a sugar-beet pectin demethylation method using ammonia that yielded gels with enough mechanical strength and insolubility, suitable for biosorption applications. After biosorption, the elution of metals could be interesting for the reutilization of exhausted biomass and the recovery of the adsorbed metals. Desorption can be carried out by proton exchange using acids, by exchange with other ions (for example $CaCl_2$) or by chelating agents (EDTA). An efficient eluant is one that desorbs the metal completely without deteriorating the biomass in case it will be reused. The objective of the present study was to investigate the properties of sugar beet pulp pectin in relation to its structural characteristics.

2. Sugar beet pulp pectin (SBPP)

A relatively new type of pectin, sugar beet pulp pectin (SBPP), has recently received much attention[17,18]. As shown in Fig. 1, SBPP is a heteropolysaccharide with a chain structure of (1 / 4)-linked a-D-galacturonic acid (GalA) units interrupted by the insertion of (1 /2)-linked L-rhamnopyranosyl residues. Rhamnosyl residues (20-80%) can be substituted with side chains ('hairy' region) consisting of neutral sugars, such as Dgalactose, L-arabinose, D xylose, D-glucose, D-mannose, L-fucose and D-glucuronic acid. In addition, lateral chains contain phenolic acids such as ferulic acid, which are linked to the arabinose and galactose residues via ester linkages[19].

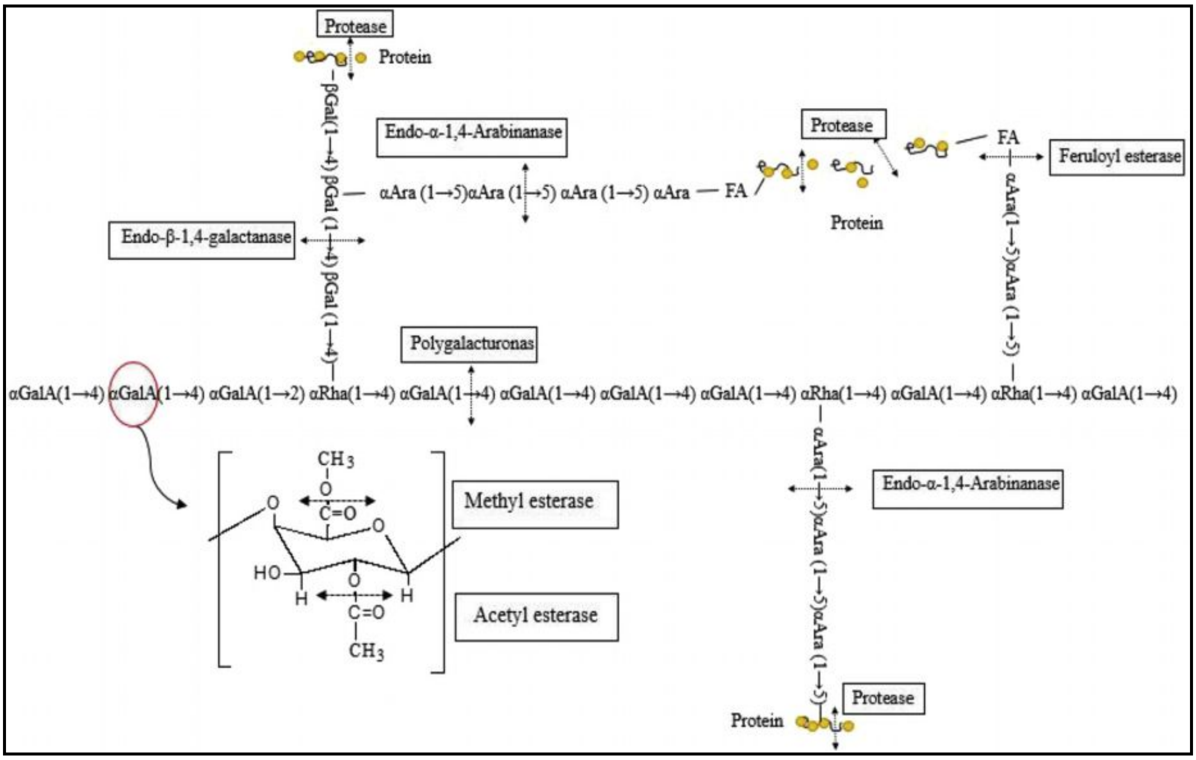

Fig. 1. Schematic figure of SBPP and enzymes used in the experiments. GalA: Galacturonic acid; Rha: Rhamnose; Gal: Galactose; Ara: Arabinose; FA: Ferulic acid.

In addition, there is a higher concentration of the proteinaceous materials bound to the side chains through covalent linkages[22]. Some of the acid groups of the GalA in the linear chain structure ('smooth' region) can be partially methyl-esterified and O-acetylated at the C- 2 and/or C-3 positions[18]. Compared to other conventional pectins, SBPP tends to exhibit a higher degree of acetylation (DA) and a greater number of neutral sugar side chains (rich in hairy regions)[18]. In addition, SBPP has a greater number of feruloyl groups attached to the galactose and arabinose side chains[27] and a greater amount of proteinaceous material bound to the lateral chains through covalent linkages[28]. Because of these differences in structural characteristics, SBPP does not have the capability to form gels like conventional pectins, but it possesses excellent emulsifying properties[28]. According to Endreß and Rentschler (1999), the emulsifying ability of beet pectin can be explained by the high percentage of acetyl groups in its chemical structure[29].

3. Technology overview

Sugar-beet/molasses ethanol production technology utilizing spray-dried yeast is illustrated in Fig. 2. Sugar-based ethanol production processes involve simple sugar molecules rather than a large amount of solid starch. Consequently the production processes require fewer operations than starch- or cellulose-based ethanol production processes[32]. As shown in Fig. 2, sugar beets are first ground before further processing. Ground pieces are pressed and extracted to produce sugar juice. The actual grinding process for preparing energy beets for biofuel is less refined compared with sugar production in which beets are sliced. Simple grinding can tolerate small rocks less than 1" in diameter which enables production in a wider variety of soil types and geographic locations. Once the juice is extracted, it is separated from solid beet pulp which is processed into animal feed. Before the final product of fuel ethanol is produced, sugar bearing juice moves through various stages of cooking, sterilization, fermentation, distillation, dehydration, and denaturing e similar to corn ethanol production.

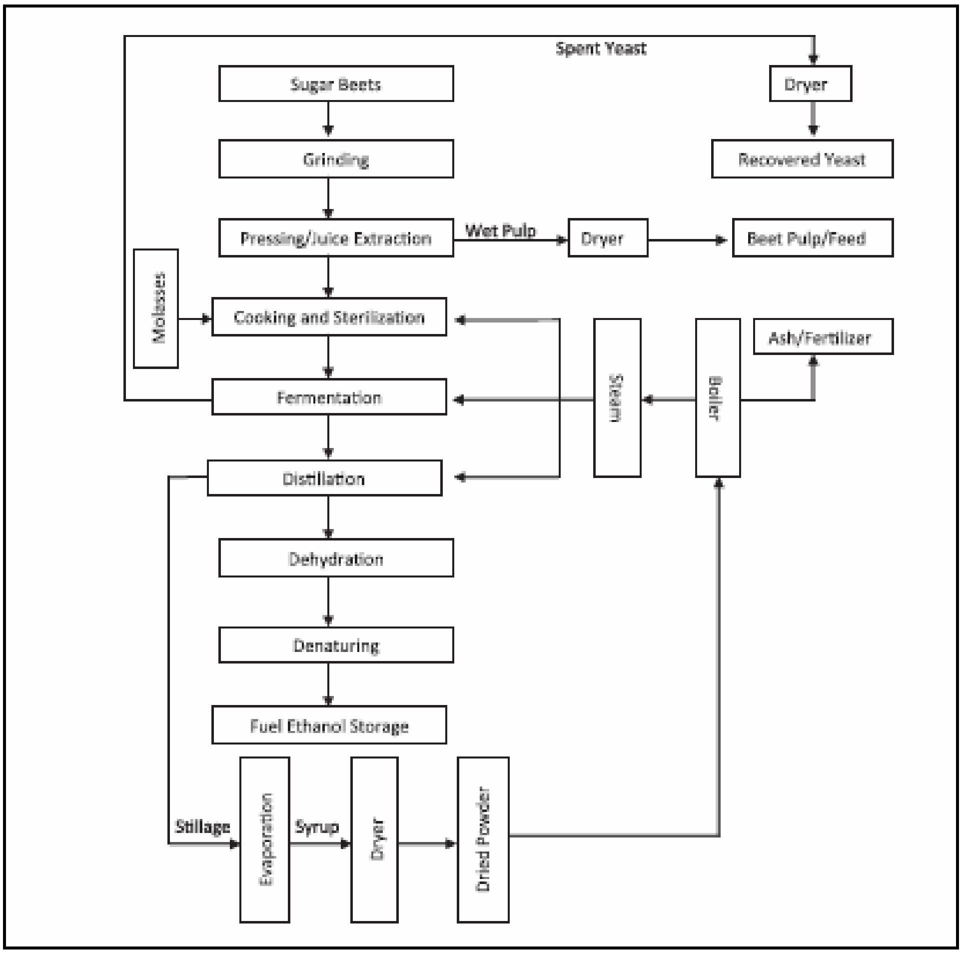

Fig.2. Sugar-beet/molasses ethanol production process flow diagram.

4. Conclusion

Economic benefits of ethanol plants primarily depend on materials, energy and resources, labor cost and investment in equipment and wear and tear, etc. In this article raw material sugar-beets and multieffect evaporation process are the major factors in the costs change. Although the costs of direct fermentation of sugar-beet juice (adjust the sugar content by adding molasses) is lower than that of sugar beet juice concentration, the multi-effect evaporation acquires a high-sugar fermentation and saves distillation and equipment costs[33]. At the same time, it also reduces the microbial infection of the squeeze juice. Part of impregnated water and diluted water are the waste from the distillation tower. Water can be recycled in the production process and reduce emissions. In addition, with this method, separating sugar-beet pulps before fermentation improves the equipment utilization of fermentation and distillation, saves energy consumption and makes the comprehensive utilization of sugar-beet pulps much easier. Enrichment process reserves the sugar, which will be able to extend the production period in ethanol plants.

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