

The Effect of Extrusion Conditions on Water-extractable Arabinoxylans from Corn Fiber

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ABSTRACT: The effect of feed moisture contents (30%, 40%, and 50%) and screw speed (200 rpm, 250 rpm, and 300 rpm) on the corn fiber gum (CFG) yield and soluble arabinoxylans (SAX) content of destarched corn fiber was investigated. The CFG yields and SAX contents of extruded, destarched corn fiber were higher than that of destarched corn fiber. In extruded, destarched corn fiber, increased screw speed and decreased feed moisture contents resulted in a higher SAX contents. The maximum yields of CFG obtained from extruded, destarched corn fiber were 79.1 ± 19.0 g/kg (30% feed moisture content) and 82.3 ± 11.30 g/kg (300 rpm screw speed). The highest SAX content was also observed at a screw speed of 300 rpm. The results of the present study show that water extraction and extrusion combined have the potential to increase CFG and SAX yields from corn fiber.

Keywords: extrusion, soluble arabinoxylans, corn fiber gum, water extraction

INTRODUCTION

Corn fiber, a by-product of the wet milling of corn kernels, is widely used as animal feed and can be used for the production of various products (1). The majority of corn fiber is lignocellulose, which consists of cellulose (150~200 g/kg), hemicelluloses (400~500 g/kg), and lignin (80~130 g/kg). Cellulose is present along with hemicelluloses, which are bound to lignin through ferulic acid. Cellulose is a chemically homogenous linear polymer of β -1,4 linked D-glucose monomers (2). Hemicelluloses are polysaccharide polymers that exist with cellulose in plant cell walls. Arabinoxylan is a hemicellulose that is commonly referred to as corn fiber gum (CFG). The structure of CFG consists of a β -(1 \rightarrow 4)-D-xylopyranosyl backbone with α -L-arabinofuranosyl residues as side units connected to the main chain by (1 \rightarrow 2) or (1 \rightarrow 3) linkages. Galactose, xylose, and arabinose side chains may also be present (3). CFG is a fairly sticky polymer with a low viscosity, a unique structure, and a high solubility. CFG is particularly valuable, as it is effective in preventing cancer and diabetes, and it may help to suppress blood cholesterol levels (4).

Most of the arabinoxylans present in corn fiber can be extracted with alkaline media (5). However, the use of such chemicals for extraction has negative effects on hu-

man health and may result in the production of hazardous waste. Using water for the extraction of arabinoxylans from corn fiber is affordable and less toxic than chemical extraction process. Wang et al. (4) reported that water extraction is effective at removing hexose components from corn fiber, leaving a solid residue that is rich in arabinoxylans. In addition, water extraction can make cellulose hydrolysis easier. Water-extractable arabinoxylans from wheat and barley have been investigated (6,7), but there are few reports on the use of water extraction to enrich arabinoxylans from corn fiber. Therefore, it is of interest to explore the utility of water as a medium for the extraction of arabinoxylans from corn fiber.

Extrusion is a valuable food processing technique that is used around the world. Extrusion has many advantages over other processing techniques, including low cost, high productivity, high speed, versatility, unique product shapes, and energy savings (8). In addition, extrusion can be used in a large number of food applications. Extrusion can alter the physicochemical properties of a product, resulting in a breakdown of the biomass structure that increases the accessibility of cellulose (2). To our knowledge, there are few researches on the effects of extrusion on water-extractable CFG. Consequently, the objective of this study was to determine

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the influence of extrusion conditions (30%, 40%, and 50% feed moisture content; 200 rpm, 250 rpm, and 300 rpm screw speed) on the product yield and soluble arabinoxylans (SAX) content of water-extracted corn fiber.

MATERIALS AND METHODS

Materials

Corn fiber was provided by Samyang Genex Co. (Seoul, Korea). On a dry solid basis, the corn fiber used in this investigation had a starch content of 153.6 g/kg, a protein content of 105.2 g/kg, a fat content of 42.4 g/kg, and an ash content of 51.5 g/kg. In addition, the raw corn fiber had a soluble fiber content of 12.3 g/kg, an insoluble fiber content of 617.3 g/kg, and a total dietary fiber content of 629.4 g/kg. Cellulase was purchased from Novozymes Co. (Bagsvared, Denmark). Termamyl (i.e., thermostable α -amylase) and the xylose standard were purchased from Sigma Chemical Co. (Steinheim, Germany).

Preparation of destarched corn fiber

To enhance the purity of the CFG and decrease the cost of subsequent purification, the starch was removed from the corn fiber prior to extraction (9). Briefly, raw corn fiber was suspended in distilled water to a concentration of 100 g/L and adjusted to a pH of 5.3~5.6 with 6 N NaOH. The resulting solution was autoclaved for 2 h with Termamyl (100 mL/kg corn fiber), and the slurry (i.e., destarched corn fiber) was washed several times with distilled water and filtered through cloth sheets. The resulting product was dried in a 50°C oven.

Extrusion pretreatment

A twin-screw extruder (THK 31T, Incheon Machinery, Incheon, Korea) was used for the extrusion pretreatment of the dried, destarched corn fiber. The extruder used for this process had the following characteristics: a 32.0 mm barrel diameter, a 23:1 L/D ratio, and a 3.0 mm diameter circular die. For one set of samples, the screw speed (200 rpm), feed rate (65 g/min), and die temperatures (140°C) were held constant while destarched corn fiber samples that had been prepared with three different feed moisture contents (30%, 40%, and 50%) were processed. For another set of samples, the feed moisture content (30%), feed rate (120 g/min), and die temperature (140°C) were held constant while, the screw speed of the extruder was set to three different speeds (200 rpm, 250 rpm, and 300 rpm). The extruded, destarched corn fiber was dried in an oven at 60°C for 12 h. After drying, the extrudates were stored in polyethylene bags at room temperature. A 0.5 mm screen was used to grind all samples prior to subsequent analyses.

Extraction of corn fiber gum

The experimental procedure for the water extraction of CFG is shown in Fig. 1. Briefly, destarched corn fiber and extruded, destarched corn fiber were suspended in distilled water and autoclaved for 60 min at 121°C. The liquid and solid fractions were separated by centrifugation (6,000 rpm for 30 min). To extract the cellulose, the resulting solid fraction was added to 1.5 L of acetate buffer : cellulase : water (1:0.5:10) and allowed to incubate for 72 h at 40°C and 150 rpm. The mixture was then separated by centrifugation at 6,000 rpm for 30 min, and the resulting solid residue was dried in 50°C dry oven at least 12 h. The liquid fractions were combined, precipitated with 2 volumes of 95% ethanol, and allowed to stand at 4°C overnight. The precipitated solid (i.e., CFG) was collected by vacuum filtration and then washed with a 1:1 mixture of 95% ethanol and acetone. The final solute was allowed to dry (i.e., final solution). The CFG (i.e., crude arabinoxylans) were freeze-dried and kept at 4°C until further analysis.

Analytical method

The phloroglucinol method was used to determine the SAX content of the destarched and extruded, destarched corn fiber samples (10). Xylose was used as a standard for SAX content determination. Briefly, 100 mg CFG samples were mixed with 1.5 mL of sodium acetate buffer (50 mM, pH 5.0) in glass screw-cap tubes. The glass tubes were shaken horizontally (150 rpm) in a 50°C water bath for 30 min and then immediately boiled for 2 min. After boiling, the samples were centrifuged at 6,000 rpm for 30 min. The supernatants were collected and SAX content was measured as described by Douglas

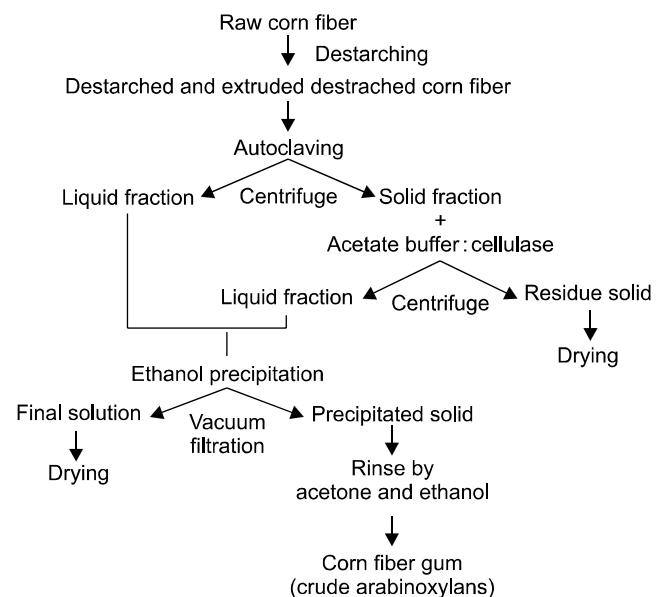


Fig. 1. Outline of the isolation of corn fiber gum from corn fiber by water extraction.

(10). A 200 μL aliquot of each supernatant from the previous step was added to tubes containing 1 mL of phloroglucinol reagent [glacial acetic acid, concentrated hydrochloric acid, 17.5% (w/v) glucose in water and 20% (w/v) phloroglucinol in ethanol]. The tubes were then capped, boiled for 40 min, and cooled rapidly. The absorbance of the samples was measured at 552 nm and 510 nm. The difference between the absorbance at 552 nm and 510 nm was used to calculate the concentration of xylose equivalents present in each sample.

RESULTS AND DISCUSSION

Effect of feed moisture content on product yield and soluble arabinoxylans content

The solid residue, CFG, and final solution yields are shown in Table 1. The solid residue yield from destarched corn fiber was 705.1 ± 5.7 g/kg. The solid residue yields from extruded, destarched corn fiber increased from 749.9 g/kg to 796.8 g/kg when the feed moisture content was increased from 30% to 50%. The extruded, destarched corn fiber with a 30% feed moisture content had the lowest solid residue yield, which resulted in the highest CFG yield and SAX content. A decrease in feed moisture content was correlated to an increase in CFG yield.

The SAX contents of the raw materials, solid residues,

Table 1. The effect of feed moisture content on solid residue, corn fiber gum, and final solution yields (Unit: g/kg)

	Solid residue	Corn fiber gum	Final solution
DCF ¹⁾	705.1 ± 5.7	28.6 ± 10.7	266.3 ± 7.1
EDCF 30%	749.9 ± 12.5	79.1 ± 19.0	171.0 ± 31.5
EDCF 40%	752.7 ± 12.5	75.7 ± 13.6	171.6 ± 26.0
EDCF 50%	796.8 ± 9.5	64.4 ± 14.5	138.8 ± 20.7

¹⁾DCF, destarched corn fiber; EDCF, extruded and destarched corn fiber.

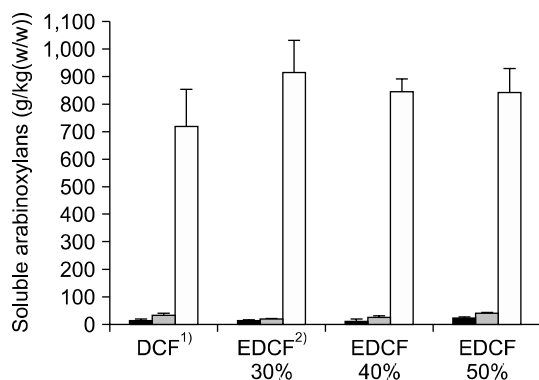


Fig. 2. The effect of feed moisture content on the soluble arabinoxylans contents of raw materials (■), solid residues (■), and corn fiber gums (□). DCF, destarched corn fiber; EDCF, extruded and destarched corn fiber.

and CFGs are shown in Fig. 2. The SAX content of CFG from destarched corn fiber was 717.3 g/kg, which was lower than those of the extruded, destarched corn fiber samples. The highest SAX content (917.0 g/kg) was observed in extruded, destarched corn fiber with a 30% feed moisture content. SAX contents increased when feed moisture content decreased from 50% to 30%. Most hexose components, such as corn fiber cellulose, in corn fiber were removed by treatment with cellulase, resulting in an increase in arabinoxylans content. These observations are consistent with those of Wang et al. (4) and Yoo et al. (11).

Effect of screw speed on product yield and soluble arabinoxylans content

Table 2 shows the effect of screw speed on solid residue, CFG, and final solution yields. The CFG yield from destarched corn fiber (28.6 ± 10.27 g/kg) was significantly lower than those of extruded, destarched corn fiber that had been processed with a screw speed of 200 rpm (77.2 ± 8.27 g/kg), 250 rpm (76.2 ± 8.11 g/kg), and 300 rpm (82.3 ± 11.80 g/kg). The SAX contents of the raw materials, solid residues and CFGs are plotted in Fig. 3. The SAX contents of extruded, destarched corn fiber increased with increasing screw speed. Karunanithy et al. (12) and Yoo et al. (13) reported that an increased screw speed might soften the lignin, that binds cellulosic fibers together, allowing them to be pulled apart and

Table 2. The effect of screw speed on solid residue, corn fiber gum, and final solution yields (Unit: g/kg)

	Solid residue	Corn fiber gum	Final solution
DCF ¹⁾	705.1 ± 5.77	28.6 ± 10.27	266.3 ± 7.1
EDCF 200 rpm	670.7 ± 19.50	77.2 ± 8.27	252.1 ± 27.7
EDCF 250 rpm	666.1 ± 10.27	76.2 ± 8.11	257.7 ± 7.1
EDCF 300 rpm	666.6 ± 22.83	82.3 ± 11.80	251.1 ± 34.1

¹⁾DCF, destarched corn fiber; EDCF, extruded and destarched corn fiber.

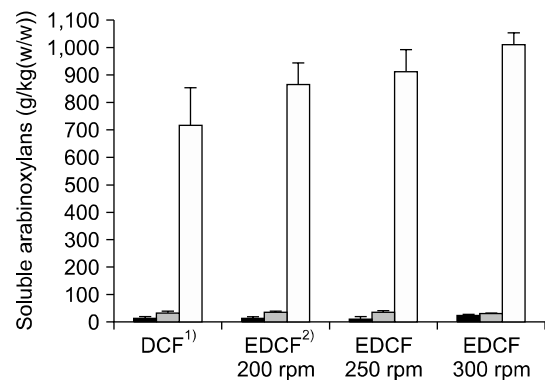


Fig. 3. The effect of screw speed on the soluble arabinoxylans contents of raw materials (■), solid residues (■), and corn fiber gums (□). DCF, destarched corn fiber; EDCF, extruded and destarched corn fiber.

separated more easily. The highest CFG yield (82.3 ± 11.80 g/kg) and SAX content (1,011.6 g/kg) were observed with the 300 rpm screw speed treatment.

CONCLUSION

This experiment was conducted to improve our understanding of the influence of feed moisture content and screw speed on water-extractable arabinoxylans from corn fiber. CFG yields and SAX contents were highest at a feed moisture content of 30% and a screw speed of 300 rpm. The CFG yields of the water-extracted samples from this study were lower than the CFG yields typically reported with chemical extraction. However, CFG yields and SAX contents were increased when water extraction was combined with extrusion, a clean technology that is good for the environment. From this study we can conclude that water extraction combined with extrusion is a feasible method for arabinoxylans production.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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