



Short communication

Comparison of two wheat bran extracts in the sheet extrusion process



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ABSTRACT

In this study the applicability of two differently purified crude wheat bran extracts for sheet manufacturing was evaluated. The sheet extrusion was chosen for material production because it is an industrially feasible large-scale process. The wheat bran extracts had different starch (45% and 11%) and protein (18% and 38%) contents but similar arabinoxylan (16% and 17%) and lignin (11% and 12%) contents. Glycerol, sorbitol, and their blends were used as external polyol plasticizers to enhance the continuous formation of the sheet during the process. With the chosen extrusion parameters, cohesive 100-mm-wide sheets were successfully produced with single screw extruder. The mechanical and thermal properties of the sheets were evaluated, as well as their water sensitivity. Sorbitol plasticization made the sheets stronger and stiffer and significantly lowered the water vapor permeability (WVP) and water vapor sorption (WVS) of the sheets as compared to glycerol plasticization. The sheets rich in starch had a higher tensile strength and elongation at break and a lower WVP and WVS than sheets with low starch content and high protein content. The strongest and stiffest sheet with the lowest WVP was the sorbitol-plasticized sheet with high starch and low protein content.

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1. Introduction

Wheat (*Triticum* spp.) is widely cultivated in the world, and its processing produces large amounts of by-products, such as bran and straw, which are a substantial reservoir of biopolymers. Wheat bran contains up to 30% arabinoxylan (AX), approximately 20% starch, and 12–20% proteins (Bataillon et al., 1998; Hollmann and Lindhauer, 2005; Ebringerová, 2006; Xie et al., 2008; Jacquemin et al., 2015). All of these biopolymers form films individually and could be utilized more efficiently than they are currently being used, for example, in biodegradable packaging and coatings. Biopolymer films are usually produced in a laboratory scale via solution casting method onto Petri/Teflon dishes. Depending on their structural features, such as molecular weight, they may require an external plasticizer to enhance cohesive film formation. In addition, with external plasticization film properties, such as the flexibility of the film can be adjusted. Cereal-based AX has been used in various film studies, either with or without external plasti-

cization. For example, oat spelt AX films were successfully formed when plasticized with glycerol, sorbitol, or their blends (Heikkinen et al., 2014; Mikkonen et al., 2009), whereas barley husk AX formed cohesive but brittle films without plasticization (Höije et al., 2005). Glycerol and sorbitol are often used polyol plasticizers in starch and protein films (McHugh and Krochta 1994; Talja et al., 2008). Although casting is a widely used technique on a laboratory scale, it has hardly ever been scaled up and is difficult to carry out continuously. Unlike casting, extrusion is a continuous process used to make films/sheets from biopolymers. Film extrusion of polysaccharides has been reported; corn cob arabinoglucuronoxylan, starch, pectin, and sugar beet pulp have been successfully utilized in sheet extrusion (Fishman et al., 2000, 2004; Rouilly et al., 2009; Bahcegul et al., 2013; Hietala et al., 2013; Akkus et al., 2014). In addition, sunflower protein isolate and soy protein films have been produced by extrusion (Zhang et al., 2001; Rouilly et al., 2006). Crude biopolymer fractions can be a feasible choice in film production and even enhance the film's material properties. A study with wood hydrolysate demonstrated that high-level purification is not always required; instead, crude hydrolysates may work as well as the upgraded fractions (Saadatmand et al., 2013).

The extraction of wheat bran and straw mixture using twin-screw extrusion has been reported in a recent work (Jacquemin

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Table 1

Main components and monosaccharide composition of the wheat bran extracts shown as a percentage of the dry matter (Jacquemin et al., 2015).

	WBE-S	WBE-P
Protein	17.9	38.2
Lignin	11.0	11.9
Total carbohydrates:	61.8	29.8
Arabinose	5.1	5.7
Xylose	11.0	11.5
Mannose	0.4	0.2
Galactose	0.8	1.0
Glucose	44.5 ^a	11.4
Ara/Xyl	0.46	0.50

^a Origin of glucose mainly starch.

et al., 2015). Here, we present the further processing of two of these extracts via single screw extrusion in an attempt to obtain continuous 100-mm-wide sheets. The composition of the extracts varied in terms of their starch and protein content, whereas the arabinoxylan and lignin content remained similar. The effects of both the extract composition and the external plasticizer on the mechanical and thermal properties, as well as water sensitivity, were evaluated.

2. Materials and methods

A twin screw extrusion fractionation process was used in the production of the two wheat bran extracts, one with high starch content (WBE-S) and another with high protein content and low starch content (WBE-P) (Jacquemin et al., 2015). Prior to the extraction, bran for WBE-S was de-starched by washing the bran with 40 °C water, and bran for WBE-P was de-starched enzymatically using α -amylase (BAN 480L, Novozyme, Denmark). The main components and monosaccharide compositions of the extracts are shown in Table 1 (Jacquemin et al., 2015).

Prior to sheet extrusion, the dried extracts were mixed with external plasticizers, water (30%, w/w of dry extract) and polyol (30%, w/w of dry extract), in a Perrier 32.00 mixer (Montrouge, France) to enhance cohesive sheet production in the extrusion process. Glycerol, sorbitol, and their blends (2:1, 1:1, and 1:2) were the polyols used in this study. Due to limited availability of WBE-S isolate, only 1:1 blend was tested. The mixture was stored in hermetically sealed bags at 4 °C for 12 h prior extrusion. The sheets were extruded using a Polylab Haake system (Karlsruhe, Germany) with a single-screw mechanism. The diameter of the screw was 18 mm, the screw speed was 100 rpm, and the compression rate was 1.8. The barrel temperature was adjusted as 50 °C/80 °C/100 °C/110 °C (die). The system was fitted with a 100-mm-wide sheet die with a 250 μ m slit thickness. After sheet extrusion, the samples were stored at 25 °C RH 60% prior to measurements, except the samples for the water vapor sorption study, which were stored at 23 °C RH 0% (P₂O₅). The thickness of the sheets was measured at five points by using a digital micrometer (Mitutoyo, Japan) with an accuracy of 0.001 mm, and the average value was calculated.

The tensile properties of the sheets were determined with a H5KT (JFC, France) universal testing machine fitted with a 100 N load cell. At least ten specimens (75 mm long and 5 mm wide, according to ISO 527-2, type 1BA) were tested for each kind of film. The grip separation and the crosshead speed were set to 55 mm and 1 mm/s, respectively.

Dynamic mechanical analysis (DMA) experiments were performed using a Triton 2000 DMA instrument (Triton Technology Ltd., UK) in single-cantilever bending mode. From the sheet samples, pieces of about 30 mm in length and 5 mm in width were cut, after which they were placed in a 'pocket' designed for biomaterials to be investigated by DMA. The temperature was ramped from



Fig. 1. Sheet production from plasticized wheat bran extract via extrusion. Width of the die is 100 mm and slit thickness 250 μ m.

–100 to 100 °C at 2 °C/min, with an applied frequency of 1 and 10 Hz and amplitude of 0.05 mm. The $\tan \delta$ was plotted as a function of temperature in order to determine the thermal relaxations, of which the α -relaxation was taken as a glass transition.

In water vapor permeability measurements, sheet specimens were clamped on 6.4-cm-radius aluminum cups containing 7 g of CaCl₂ (RH 0%) as a desiccant. The cups were then placed in a climate room with a controlled atmosphere (25 °C and RH 60%) and weighed once a day for 7–10 days. The water vapor transfer rate (WVTR) and water vapor permeability (WVP) were calculated as described earlier (Heikkinen et al., 2013). Three parallel samples were tested for each sheet type.

A DVS intrinsic sorption microbalance (Surface Measurement Systems, Alpertown, UK) was used for the water vapor sorption study, as described previously (Heikkinen et al., 2013). The measurements were carried out at a humidity range of 0–90% at 25 °C. Two parallel samples were tested.

3. Results and discussion

With both studied extracts (WBE-S and WBE-P) plasticized with polyol, 100-mm-wide continuous sheets were successfully produced by single-screw extrusion (Fig. 1). The thickness of the sheets varied, with the average values being between 280 μ m to 655 μ m. The thickness was larger than the slit of the extrusion die, which was caused by the expansion of the material at the extruder output. In pre-tests, slit thicknesses of 100, 250, and 400 μ m were tested, and the most regular and continuous sheets were obtained with a slit thickness of 250 μ m, regardless of the screw rotation speed used (75, 100, and 125 rpm). For traditional thermoplastics, low thicknesses are achieved by using post-extrusion treatments, such as blowing or calendaring, which are rarely possible with natural

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