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Microfiltration of gluten processing streams from corn wet milling

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Abstract

In corn wet milling, dry matter can be separated from liquids in process streams with centrifuges or vacuum belt filtration (VBF). Because separations usually are not complete, dry matter can be lost in the liquid streams (overflow from the gluten thickener centrifuge and filtrate from VBF). This represents a loss of nutrients, especially protein, to low valued coproducts and reduces quality of water for recycling within the process. The objective was to compare microfiltration of light and heavy gluten process streams to conventional separation methods. Batches of light and heavy gluten were obtained from a wet mill plant and processed by microfiltration. Samples of permeate and concentrate from microfiltration were analyzed and compared to corresponding streams from wet milling. Microfiltration of light gluten resulted in concentrate and permeate streams similar in composition to conventionally processed light gluten using a centrifuge, suggesting that microfiltration is as effective as centrifugation in partitioning solids and water in light gluten. Dewatering of heavy gluten found that conventional VBF caused dry matter concentrations in gluten cake to be higher than concentrate from microfiltration. Permeate from microfiltration of heavy gluten had higher concentrations of ash and lower soluble nitrogen than filtrate from VBF. Microfiltration was able to remove more ash from concentrate, which may improve the value of wet milling coproducts. These data demonstrated microfiltration has potential for separation of light and heavy gluten streams, but more data are needed on effectiveness and practicality.

Keywords: Coproducts; Nutrient composition; Corn processing; Membrane filtration; Corn gluten meal; Wet milling

1. Introduction

Wet milling is a major technology for processing corn. In wet milling, corn is steeped for 24–36 h, germ and fiber are removed, and the resulting slurry is separated into two streams (Blanchard, 1999; Johnson and May, 2003). One stream contains highly concentrated starch. The second stream (light gluten) is dilute (2–6% dry matter) and consists mainly of proteins. Light gluten is separated by centrifugation (gluten thickener) into a heavy gluten stream (12–17% dry matter) and an overflow stream (defined as "overflow", 2–3% dry matter). Heavy gluten is separated with a vacuum belt filter (VBF) into gluten cake and filtrate (defined as "filtrate"). Gluten cake is dried to form corn gluten meal, a high protein (67% db) coproduct used in animal diets (Blanchard, 1999).

These two separation steps (centrifugation and VBF) are not 100% effective in recovery of dry matter and protein, and considerable amounts are in the overflow from the gluten thickener centrifuge and filtrate from VBF,

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which are recycled in the wet milling process. Rausch et al. (2002) reported that about 40% of protein in light gluten was found in the overflow and that about 10% of the protein in heavy gluten was found in filtrate. More effective separation would increase recovery of protein (which is marketable as animal feed) and improve quality of process water. Also, water removal using current technology is costly; alternative approaches could have significant economic impacts.

Technological advances in membrane design, such as use of stainless steel and ceramic materials in construction, have resulted in filtration systems that are more cost effective and more efficient. However, limited data have been reported on the effectiveness of membrane filtration systems to process gluten streams. Singh et al. (1998) found that a laboratory scale microfiltration system could increase dry matter content of a light gluten stream from 5.2 to 9.2 g/100 g; they recovered 20% more soluble material in the concentrate. Recently, we reported when light gluten is processed in wet milling, elements were concentrated in the resulting liquid streams (overflow and filtrate), while proteins and other organic materials were concentrated in the corresponding solid streams (heavy gluten and gluten cake, Rausch et al., 2003). Data are needed to evaluate the effectiveness of microfiltration to process gluten processing streams. The objectives were to: (1) determine effectiveness of microfiltration systems to process light and heavy gluten streams, and (2) compare characteristics of microfiltration streams to corresponding wet milling streams.

2. Methods

2.1. Description of membranes and equipment

Two membranes systems were compared. Membrane modules with nominal length of 1.50 m (0.35 m^2 membrane area, model 2.5-750A-5P, Graver Technologies, Glasgow, DE) or 3.05 m (0.70 m^2 membrane area, model 2.5-750A-10P, Graver Technologies, Glasgow, DE). The first membrane system (MF1) used a single 1.50 m stainless steel tubular membrane module with a membrane area of 0.35 m^2. The second membrane system (MF2) used two 0.70 m^2 and one 0.35 m^2 membrane modules in series, for a total membrane area of 1.75 m^2. Each membrane module had tube and shell configurations containing four tubes; each tube had an internal diameter of 1.90 cm, and a nominal pore size of 0.1 μm. All modules were constructed using the same porous stainless steel material.

Each system (MF1 and MF2) included a batch tank, pump, heat exchanger and membrane modules; these were configured in a loop to concentrate test materials (Fig. 1). A rotary lobe pump (P0399155, Waukesha Pumps, Waukesha, WI) was connected to a 7.5 Hp

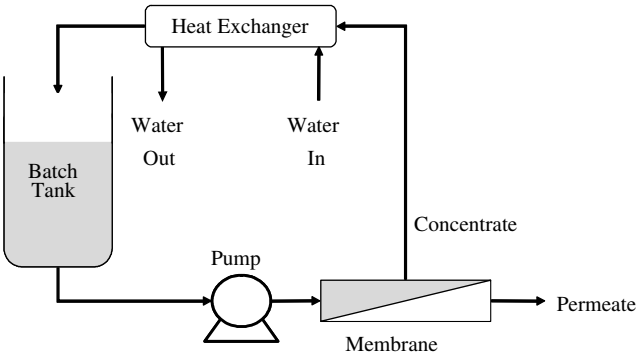

Fig. 1. Schematic of batch filtration of light and heavy gluten samples.

electrical motor and a digital variable frequency drive (AF-300 P11, Fuji Electric, Yokosuka City, Japan) to maintain 280–300 L/min and a crossflow velocity within the membrane module of 4.5 m/s in the loop, according to membrane manufacturer's recommendations. Membranes were configured so that material was pumped through the tube interior and permeate passed through to the outside of the tubes and collected. Preliminary testing over a range of transmembrane pressures (TMP) prior to filtration tests indicated that a TMP of 200 kPa provided permeate flux rates that were sufficient for subsequent filtration experiments. For MF1, the batch tank was 200 L (nominal capacity). For MF2, the batch tank was 400 L to allow larger volumes of test materials and higher concentration of dry matter when filtering.

2.2. Experiment 1. Comparison of membranes

There were no published data available on membrane processing of gluten streams. The goal of this experiment was to obtain basic performance data, such as permeate flux rate, dry matter separation, dry matter concentrations and membrane fouling for MF1 and MF2. Batches of light gluten (~400 L) were obtained from the light gluten storage tank in a commercial wet milling plant. These were stored at 4–6 °C while experiments were being carried out. MF1 was evaluated first, followed by MF2. Microfiltration using MF1 lasted 9–10 h; microfiltration using MF2 lasted 2–3 h. For each replicate, light gluten was added to the batch tank, and pumping and filtration started. Permeate flux rate was determined by measuring the volume of permeate generated over a 1 min period, then calculating permeate flux rate by dividing volumetric flow rate (L/h) by membrane area of 0.35 and 1.75 m^2, for MF1 and MF2, respectively, to determine L/m^2/h (LMH). Each microfiltration evaluation was done twice; for each replicate, 1 L samples of permeate and concentrate were collected at 3–5 time intervals during filtration and analyzed in duplicate for dry matter based on change in permeate flux rate during filtration of each batch. As