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Fractionation of oats into products enriched with protein, beta-glucan, starch, or other carbohydrates

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ABSTRACT

A modified wet method was developed to fractionate ground oat groats into 4 fractions enriched with beta-glucan (BG), protein, starch, and other carbohydrates (CHO), respectively. Effects of defatting oats and centrifuge force for separation were also investigated. Results show that, depending on the two factors, nutrient concentrations in the corresponding fractions ranged 28.53–44.84% (dry matter) for BG, 72.41–92.62% for protein, 79.13–81.69% for starch, and 37.47–42.16% for other CHO. Nutrient recoveries from each fraction were 39.82–51.20% for BG, 60.36–72.08% for protein, 77.04–87.25% for starch, and 24.87–29.68% for other CHO. For the protein fraction, defatting improved the protein content but did not on its recovery. For the starch fraction, the effect of defatting was just opposite, improving the starch recovery but not the starch content. Centrifuge force increased the BG content in the BG fraction when the defatted sample was used. The cumulative recovery of each component in the combined fractions was not affected by oil removal or centrifuge force. Overall, the wet method described was relatively effective in recovering the major nutrients from oats into their respective fractions, while it alleviated the problems of viscous slurry upon mixing ground oat groats with an alkaline solvent and the difficulty of slurry separation.

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1. Introduction

Oat ranks seventh in world cereal production, preceded by corn, rice, wheat, barley, sorghum, and millet. It has relatively higher contents of oil and protein than other cereal grains (Pomeranz, 1982)). Furthermore, oat is among the very few grains that contain physiologically significant amounts of mixed linkage (1,3-1,4) beta-D-glucan (BG) (Peterson, 1992). BG is water soluble and has become one of the most important dietary fibers for human health, as clinical studies have shown that BG has cholesterol lowering effects (Othman et al., 2011).

There has been considerable interest in producing fractions enriched with BG, protein, and/or starch from oat and other grains, with numerous methods being described (Vasanthan and Temelli, 2008). In general, the methods can be grouped into dry fractionation (Knuckles et al., 1992; Stevenson et al., 2008; Liu et al., 2009; Sibakov et al., 2011) and wet extraction/separation (Cluskey et al., 1973; Wu et al., 1977; Wood et al., 1977; Inglett, 1992, 2000; Vasanthan and Temelli, 2002). In contrast to dry methods, wet fractionation requires solvents and chemicals, can potentially lose some health beneficial components, and is expensive, but it allows enrichment of multiple nutrients, each having high concentration and production yield.

With respect to wet fractionation for protein enrichment, Cluskey et al. (1973) described a process based on alkaline extraction and investigated optimal conditions for oat protein extraction, using ground groats. The composition and some properties of the resulting oat protein concentrates have been described elsewhere (Wu et al., 1973). Using a similar wet method, the same group was able to produce a protein isolate from defatted oat groats (Wu et al., 1977). Later on, Ma (1983a, 1983b) further investigated methods, composition, and functional properties of oat protein concentrates and isolates.

Wet processes for isolating BG from oats and/or barley are also available (Vasanthan and Temelli, 2008). These include alkali extraction and alcohol precipitation (Wood et al., 1977, 1978; Bhatty, 1993), an aqueous enzymatic method (Inglett, 1992), an aqueous thermo-mechanical method (Inglett, 2000), and an aqueous alcohol based enzymatic treatment (Vasanthan and

Abbreviations: BG, beta-glucan; CHO, carbohydrate; dm, dry matter.

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Temelli, 2002). However, one common problem with wet methods is that the alkaline slurry of ground oat groats becomes viscous and is difficult to filter (Cluskey et al., 1973; Wood et al., 1978; Ma, 1983a; Vasanthan and Temelli, 2008). Among the reported studies on oat fractionation, almost all dealt with enrichment of one (BG) or two (protein and starch) components, and many focused on nutrient concentrations in resulting fractions but neglected recovery. Furthermore, although both regular and defatted oat groats were used for BG or protein enrichment, there were limited studies for a direct comparison of the two types of oat materials upon dry fractionation (Sibakov et al., 2011) or wet processing (Wu et al., 1973; Ma, 1983a). Therefore, more work is needed to delineate the effect of oil removal (defatting) on nutrient enrichment and recovery upon oat fractionation.

In the present study, a modified wet method was developed to achieve multiple objectives: (1) to fractionate oat groats into several value-added ingredients, each enriched with protein, BG, starch and other carbohydrate (CHO), respectively, (2) to alleviate the problem of viscous alkaline slurry and difficulty of its separation, and (3) to investigate the effects of oil removal and centrifuge force on concentrations and recovery rates of the 4 nutrients in the resulting fractions.

2. Materials and methods

2.1. Preparation of materials

The hulless oat variety Lamont was grown in Aberdeen, Idaho, USA, under normal irrigated conditions. Upon harvest, seed samples were passed through a screen with a code L, 5/64″ × ¾″ (1.98 × 19.04 mm) slotted (Seedburo Equipment Co., Chicago, IL) to remove broken kernels and foreign material, and then fed into a Lab Huller (Model 5095, Codema, Inc., Minneapolis, MN) for removing any remaining hulls. The oat groats were ground into powder (passing No. 40 U.S. standard mesh, with sieve opening dimensions of 425 μm) with a household Burr grinder (Model 3045, Braun, Cincinnati, OH). A portion of the powder was defatted by mixing with hexane (solvent: solid ratio = 5:1) for 1 h and centrifuging at 2500× *g* for 10 min (Centra GP8R, Thermo Electron Corp.). Hexane in the supernatant was recovered through evaporation and the remaining oil was discarded. The precipitate (defatted ground oat groats) was desolventized by spreading it in a pan and holding the pan under a vented hood overnight.

2.2. Wet extraction and experimental design

The experiment was based on a factorial design, with 2 factors and each having 2 levels. For oil removal from the starting material (ground oat groats): regular vs. defatted; for the centrifuge force used for liquid–solid separation: 1000 vs. 3000× *g* (by the above centrifuge). All the centrifuging steps during wet extraction used the same centrifuge force (either 1000 or 3000× *g*) for a single run and same centrifuge time (20 min) for all runs. The experiments were duplicated at the sample preparation stage. The procedure of wet extraction consisted of the following 3 stages (Fig. 1).

2.2.1. BG extraction and recovery

Briefly, 75 g (as is) ground oat groats (non-defatted or defatted) was mixed with 500 ml water (75:500 = 1:6.7 solid to solvent ratio) by a mechanical mixer (IKA, model RW20, 1500 RPM) for 20 min. Upon centrifugation, the supernatant was mixed with 95% ethanol so that the final ethanol concentration reached 50% (v/v). The new mixture was centrifuged. The precipitate was saved as the BG fraction, while the supernatant was evaporated to recover ethanol and the remaining liquid was discarded.

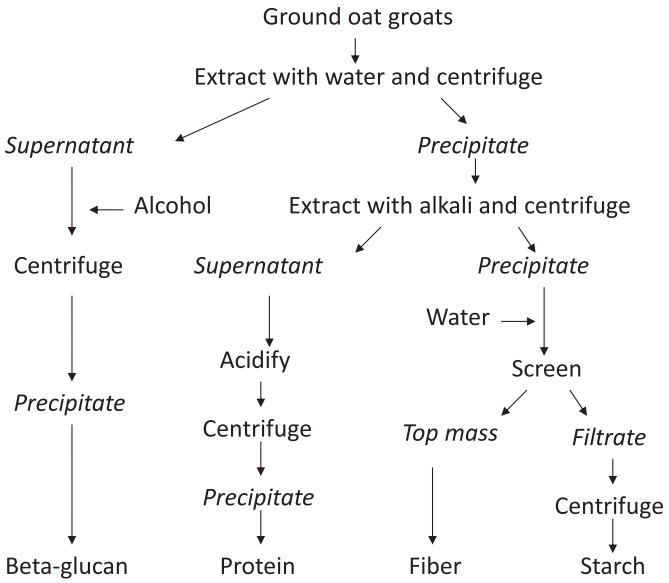

Fig. 1. Flow chart of the modified wet method to fractionate oats.

2.2.2. Protein extraction and recovery

The precipitate of the initial water extraction was mixed with 400 mL of 0.075 M NaOH (75:400 = 1: 5.5 initial flour to solvent ratio) by a mechanical mixer for 10 min. Upon centrifugation, the supernatant was saved and combined with the supernatant from centrifuging the underpass of screening from Stage (2.2.3). The mixture was acidified with 2 N HCl to a pH of 5.2, and centrifuged. The new supernatant was discarded and the new precipitate was saved as the protein fraction (also known as the oat protein concentrate).

2.2.3. Starch separation and recovery

The precipitate from centrifuging the alkaline extraction at Stage (2.2.2) was mixed with 200 mL water for 10 min before screening with a U.S. Standard mesh No. 270 (53 μm). The material retained on the screen was saved as a fiber fraction. The material passing though the screen was centrifuged. The supernatant was saved and used for the protein recovery in Stage (2.2.2). The top layer of the precipitate was scraped off and saved as the starch top fraction. The remaining precipitate was the starch fraction.

2.3. Chemical analysis

All wet fractions were dried in a forced-air oven at 60 °C overnight. Dried fractions plus the starting materials (regular and defatted oat powders) were weighed and measured for moisture, protein, oil, ash, BG, and starch contents. Moisture and ash contents were determined according to official methods (AOAC, 2002). Moisture content was used to convert the contents of other components into a dry matter basis. The total nitrogen/protein content was measured by a combustion method (AOAC, 2002), using a protein analyzer (Model FP-528, Leco Corp. St. Joseph, MI, USA). The protein content was calculated with a conversion factor of 6.25. BG was measured according to Method 995.16 (AOAC, 2002), using the beta-glucan assay kit supplied by Megazyme Intl. Ireland Ltd. (Wicklow, Ireland). The oil content was determined by an Official Procedure (AOCS, 2005), using a fat analyzer (Model XT 10, Ankom Technology, Macedon, NY USA). However, instead of using petroleum ether, hexane was the extracting solvent. Starch was measured according to an enzymatic method described elsewhere (Liu and Han, 2012). The total CHO content was calculated based on