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Dietary fibre enrichment from defatted rice bran by dry fractionation

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ABSTRACT

Defatted rice bran is excellent source of dietary fibre. The mostly used lab-scale method to extract dietary fibre is not very efficient; dry fractionation is a more energy efficient alternative at larger scale. Three separation routes were studied: two-step electrostatic separation, sieving and a combination of electrostatic separation and sieving. All yielded fibre-enriched fractions with similar yield (20–21%) and purity (67–68% dm), which recovered 42–48% of the fibre from original rice bran flour. The enriched fraction obtained by two-step electrostatic separation contained more small particles and possibly different DF composition compared to the other two, which resulted in different functional properties. Compared to dietary fibre extracted by enzymatic-gravimetric method, enriched fractions by dry fractionation have a similar water retention capacity and oil bind capacity. This suggests that fibre-enriched fractions by dry fractionation can be applied in foods and provide similar technological and physiological properties as wet-extracted dietary fibre does.

1. Introduction

Rice is a staple food for more than half of the world's population (Childs, 2004). The annual global production of paddy rice in 2013 was 740.9 million metric tons (FAOSTAT, 2015). The bulk of the rice is consumed as white rice (Childs, 2004), yielding annually approx. 60 million metric tons of rice bran as a co-product from rice milling, of which the major part is underutilized as animal feed or discarded directly (Orthoefer and Eastman, 2004).

Rice bran consists of several layers, i.e. the pericarp, testa (seed coat), nucellus and aleurone layers. During rice milling, a small portion of the starchy endosperm may also end up in the bran fraction (Shibuya and Iwasaki, 1985). Rice bran contains a relatively high amount of oil (17.4–22.9 g/100 g dry bran), protein (14.0–18.1 g/100 g dry bran) and dietary fibre (27.0 g/100 g dry bran) (Abdul-Hamid and Luan, 2000; Chinma et al., 2015; Kahlon and Chow, 2000; Orthoefer and Eastman, 2004). Furthermore, it is also rich in micronutrient, e.g. vitamins and trace minerals (Saunders, 1985). Direct use of the whole rice bran is problematic, because it rapidly becomes rancid due to the hydrolysis of neutral fat by highly active lipase enzymes right after the milling (Sibakov et al., 2013). Therefore the rice bran needs to be either stabilized or further processed into different fractions for food application. The primary product from rice bran is rice bran oil because of its high nutritional value (Friedman, 2013; Lakkakula et al., 2004; Orthoefer and Eastman, 2004). Pressing and solvent extraction are the two main commercially available methods for rice bran oil production (Terigar et al., 2011). Other methods, such as supercritical fluid (SFE) and aqueous extraction also have been studied (Hanmoungjai et al., 2000; Tomita et al., 2014). After oil extraction, the residual defatted rice bran can be further valorised for dietary fibre production (Abdul-Hamid and Luan, 2000; Daou and Zhang, 2011, 2014; Nandi and Ghosh, 2015).

Dietary fibre from rice bran mainly contains cellulose, lignin and hemicellulose, of which the main part is insoluble (Chinma et al., 2015; Elleuch et al., 2011). Insoluble dietary fibres promote human health by supporting the growth of the intestinal microflora, increase the faecal bulk and decrease the intestinal transit (Foschia et al., 2013). Furthermore, the dietary fibre includes components such as ferulic acid, which exert beneficial health effects to the human intestine and provide antioxidant activity (Daou and Zhang, 2011; Mod et al., 1978; Vitaglione et al., 2008). Dietary fibre from rice bran has a very high water- and oil-absorption capacity (Abdul-Hamid and Luan, 2000; Daou and Zhang, 2014; Nandi and Ghosh, 2015), indicating its potential for preparing food products, e.g. gluten-free bread, pasta and meat product, to avoid syneresis and modify the food structure, and to stabilize high-fat food (Chinma et al., 2015; Choi et al., 2009; Elleuch et al., 2011; Hu et al., 2009; Kaur et al., 2012; Sairam et al., 2011; Saunders, 1985). Compared to other cereal brans such as wheat bran and oat bran, rice bran is

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still underutilized as a source for dietary fibre. Considering its functional and nutritional potential and its availability as a cheaper source of dietary fibre than other cereal brans (Chinma et al., 2015), it is interesting to enrich dietary fibre from rice bran as food ingredient.

Currently an AOAC enzymatic-gravimetric method for analysing dietary fibre (Prosky et al., 1988) is most often applied with modification to extract dietary fibre from rice bran on smaller scales (Abdul-Hamid and Luan, 2000; Bunzel et al., 2003; Daou and Zhang, 2011; Nandi and Ghosh, 2015). The defatted rice bran is first digested with heat-stable α-amylase, protease and amyloglucosidase at 100 °C, 60 °C and 60 °C, respectively, to remove the starch and protein. Then four volumes of 95% ethanol are added to precipitate the soluble dietary fibre. After precipitation the mixture is filtered and the residue is washed and oven-dried to obtain the total dietary fibre.

This procedure is in lab scale and not suitable for larger-scale production, because it is energy inefficient, generates solvent (ethanol) emissions and uses expensive enzymes. To allow larger-scale production, a process that is cheaper and more efficient in terms of water and energy usage is needed. Therefore in the present study, a dry fractionation process by combining milling and dry separation methods, e.g. sieving and electrostatic separation, is applied, which is more efficient in terms of water and energy consumption, and does not need any solvents. (Pelgrom et al., 2013; Schutyser and van der Goot, 2011).

The combination of milling and electrostatic separation is effective to fractionate wheat bran and oat bran into fibre-rich and fibre-depleted fractions (Chen et al., 2014; Hemery et al., 2011; Sibakov et al., 2014; Wang et al., 2015b). The separation is based on the histological structure of the bran. Different layers of the bran are dissociated from each other and broken down to small particles by milling. Then the particles are tribocharged by passing through a tube by entrainment in a gas. Because of the difference in composition, fragments from different layers obtain different charges which then enables subsequent separation under the influence of an external electric field (Wang et al., 2015b). The pericarp that is fibre-rich was enriched in negatively charged fractions, whereas the other components, e.g. starch, protein and aleurone cells, were enriched in the positively charged fractions. Compared to conventional dry separation processes such as sieving and air classification, electrostatic separation provides a different or an additional driving force for separation. Combining different separation methods, e.g. applying a sieving or air classification additional to electrostatic separation, can further improve the enrichment (Sibakov et al., 2014; Wang et al., 2015b). Since rice bran has a similar histological structure as wheat and oat bran, a similar separation by dry fractionation is expected.

The aim of this study was therefore to investigate the possibility of enriching dietary fibre from defatted rice bran by dry fractionation. Instead of using the by-product from industrial rice bran oil production, we prepared the defatted rice bran in our own lab to have well-defined starting material. For this the brown rice was pearled and defatted. We also preferred this approach as the commercial process for oil extraction, which may be either mechanical pressing or solvent extraction at elevated temperature, provides rice bran with higher residual fat content around 4–5% (Terigar et al., 2011).

For the rice bran we first we analysed the arabinoxylans content of hand-isolated bran layers to find the maximum theoretical purity can be reached by dry fractionation. Arabinoxylans were chosen to represent the dietary fibre because it is the main hemicellulose from rice bran (Mod et al., 1978; Shibuya and Iwasaki, 1985). We determined the relation between the arabinoxylans content and total dietary fibre content by analysing both contents for different samples obtained after fractionation. Two-step electrostatic separation, sieving and a combination of electrostatic separation and sieving were applied, respectively, to the finely milled defatted rice bran flour. Then the fibre-enriched fractions from different processes were compared for yield and purity. Finally, we analysed the functional properties, e.g. swelling capacity (SC), water retention capacity (WRC) and oil binding capacity (OBC), of the fibre-enriched fractions to explore the potential of the enriched fractions as ingredient for food preparation.

2. Materials and methods

2.1. Material

Brown rice (*Oryza sativa* L.) was purchased from Windkorenmolen De Vlijt (the Netherlands).

2.2. Hand-isolation of pericarp, aleurone layer and starchy endosperm

After removing the germ and grain ends, the brown rice was soaked in water for 12 h to reduce the adhesion between different layers. Then the grain was cut into two pieces by a razor-blade, and the pericarp and aleurone layer were peeled off gently by using a tweezer and a scalpel. Starchy endosperm was scraped off from the peeled part by a scalpel. The isolated tissues were defatted using acetone with a material to solvent ratio 1:8. After drying in an oven at 50 °C, the tissues were analysed for arabinoxylans content.

2.3. Preparation of defatted rice bran flour (DRBF)

Crude rice bran was obtained by milling (pearling) the brown rice with a Grain Testing Mill (Satake, Japan). The germ and broken grains were removed by sieving the crude bran with an 800 μm sieve. The obtained rice bran was about 10% of the brown rice weight. The rice bran was then defatted by using petroleum ether with a material-to-solvent ratio 1:6 for 24 h to stabilize the bran. After defatting, the bran was milled using a pin mill (Hosokawa Alpine, type 100 UPZ, Augsburg, Germany) at ambient temperature at a speed of 22,000 rpm, air flow of 75 m^3/h. The obtained defatted rice bran flour (DRBF) was stored in a −20 °C freezer until use.

2.4. Separation of DRBF by electrostatic separation and sieving

Electrostatic separation of the defatted rice bran flour (DRBF) was done with a custom-designed bench-scale separator described in a previous study (Wang et al., 2015a), with the following settings: dosing rate of DRBF 2 kg/h, flow rate of the carrier nitrogen gas 20 L/min, the applied voltage to the positive electrode 20 kV and the distance between the electrodes 10 cm. From each experiment four fractions were obtained: one from the ground electrode (GE), one from the positive electrode (PE), one from the collecting filter bag below the ground electrode (GC) and one from the collecting filter bag below the positive electrode (PC) (Fig. 1). For two-step electrostatic separation, the fraction PE was subjected to a second separation step which yielded another four fractions (PE-GE, PE-GC, PE-PE and PE-PC).

Sieving was done using an air jet sieve (Alpine200 LS-N, Hosokawa-Alpine, Augsburg, Germany) with a 50 μm sieve at 4000 Pa for 2 min. Direct sieving of the DFRB yielded two fractions: coarse (C) and fine (F). The 50 μm sieve was chosen based on the particle size distribution of the DRBF (Fig. 2). The two large and clear peaks indicate that the DFRB contains materials with different grinding behaviour, which is likely a result of their different biochemical compositions. For the combination of electrostatic separation and