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Simultaneous recovery and purification of rice protein and phosphorus compounds from full-fat and defatted rice bran with organic solvent-free process

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We studied a process that enables simultaneous recovery of protein and phosphorus compounds from rice bran. Phosphorus substances in full-fat and defatted rice bran such as phytic acid and inorganic ions were solubilized under acidic conditions in the first step. After that, inorganic and/or organic phosphate salts were recovered in insoluble form under weak alkaline conditions. Furthermore, protein fractions obtained after phosphorus compounds had been removed were solubilized under alkaline conditions. After solubilization, protein fractions with high content were recovered by isoelectric precipitation (IP) followed by electrolyzed water treatment (EWT). The highest protein content (52.3 w/w%) was attained when machine defatted rice bran was treated through the process. Energy-dispersive X-ray spectroscopy (EDX) and inductively coupled plasma atomic emission spectrometry (ICP-AES) analyses demonstrated efficient desalting from the protein fractions by EWT and higher phosphorus contents (15.1–16.4 w/w% P) in the phosphorus fractions compared with commercial phosphate rock. In addition, no heavy metal ions in either protein or phosphorus fractions were detected. These results suggest that the newly developed process is suitable for practical recovery of highly concentrated protein and phosphorus compounds from rice bran without enzymes or chemicals such as organic solvents, buffering agents, and surfactants.

[**Key words:** Full-fat rice bran; Machine defatted rice bran; Isoelectric precipitation; Electrolyzed water; Rice protein; Phosphorus compounds]

World rice production in 2008 was approximately 661 million metric tons (1), and the weight ratio of bran to whole rice particles was about 10% (2). Therefore, rice bran has been focused on as a potential resource of nutrients and elements all over the world. Rice bran is known to be a major by-product of rice polishing that contains germ and several histologically identifiable soft layers such as pericarp, seed coat, nucellus, and aleurone layers (3).

Rice protein has a great deal of potential to be a functional food when it is used in ingredients and nutritional supplements because its protein efficiency ratio (1.6–1.9) is comparable to that of casein (2.5) (1).

Thus, protein production from rice bran has been extensively studied. Physicochemical treatments that include solvent extraction (4,5), compressed hot water extraction (6), and enzymatic treatments using endoprotease, exoprotease, xylanase, phytase, amylase, and carbohydratase (1), are currently being used for effectively extracting protein from rice bran. However, these known methods involve high levels of energy consumption, harmful chemicals, and high labor costs. Therefore, the rice processing industry has to consider commercialization in extracting proteins from this material while keeping low energy consumption and production costs low.

Rice bran also includes a relatively large amount of phosphorus compounds (2). Phytic acid is particularly known to be a major constituent of the organic phosphates in rice bran. It serves as a phosphorus storage compound in plant seeds as well as a natural antioxidant because of its chelating property in iron and zinc as well as its ability to decrease the catalytic activities of many divalent transition metals (7,8). In addition, the expected global peak of phosphorus production is predicted to occur around 2030 (9). It is widely acknowledged within the fertilizer industry that the quality of remaining phosphate rock is decreasing and production costs are increasing. Technologies for recycling phosphorus from waste and extracting it from unused resources have attracted a great deal of attention because of this difficulty with producing phosphorus predicted in the future. Considering the potential of rice bran as protein and phosphorus sources, the development of safe and low-cost methods to recover these nutrients may partly contribute to establishment of sustainable use of renewable resources. However, simultaneous recovery of proteins and phosphorus compounds from rice bran by using solvent-free process has not been demonstrated.

We developed a novel process in this study that could produce highly concentrated proteins and phosphorus compounds simultaneously without organic solvents that can be applied to commercial use. We analyzed their concentrations, recovery ratios, and chemical compositions. In addition, a technique of isoelectric precipitation combined with electrolyzed-water treatment (IP-EWT)

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was intensively focused on in terms of protein content and efficiency of desalination and protein purification.

MATERIALS AND METHODS

Materials Raw (full-fat) rice bran (fat content: 20 w/w%) was prepared from brown rice (*Oryza sativa*, cv. Koshihikari, harvested in Niigata prefecture, Japan) by using a rice polishing machine (NCP100B; Satake Co., Ltd., Higashi-Hiroshima, Japan) (10). The raw rice bran (supply rate of 120 kg/h) was machine defatted to prepare defatted rice bran (approximately 50% defatted) by using an oil press (V-05W; Suehiro EPM Co. Ltd., Yokkaichi, Japan) after pre-heating the raw rice bran at 110–125°C.

Experimental procedures Rice protein and phosphorus concentrates were prepared using acid and alkaline extraction, followed by the isoelectric precipitation (IP) and a washing process with electrolyzed/distilled water, as shown in Fig. 1.

Thirty grams of raw rice bran or a defatted rice bran sample and 300 ml of deionized water (less than 2 μS cm^{-1}) were placed into a vessel, and pH was adjusted to 3.5 by using a 6 N HCl solution to elute the phosphorus compounds from the rice bran. After that, the vessel was centrifuged at 5000 ×*g* for 10 min at ambient temperature to separate eluted phosphorus compounds (supernatant) from rice bran residue (precipitate). The supernatant was adjusted to pH 7.5 with 6 N NaOH to

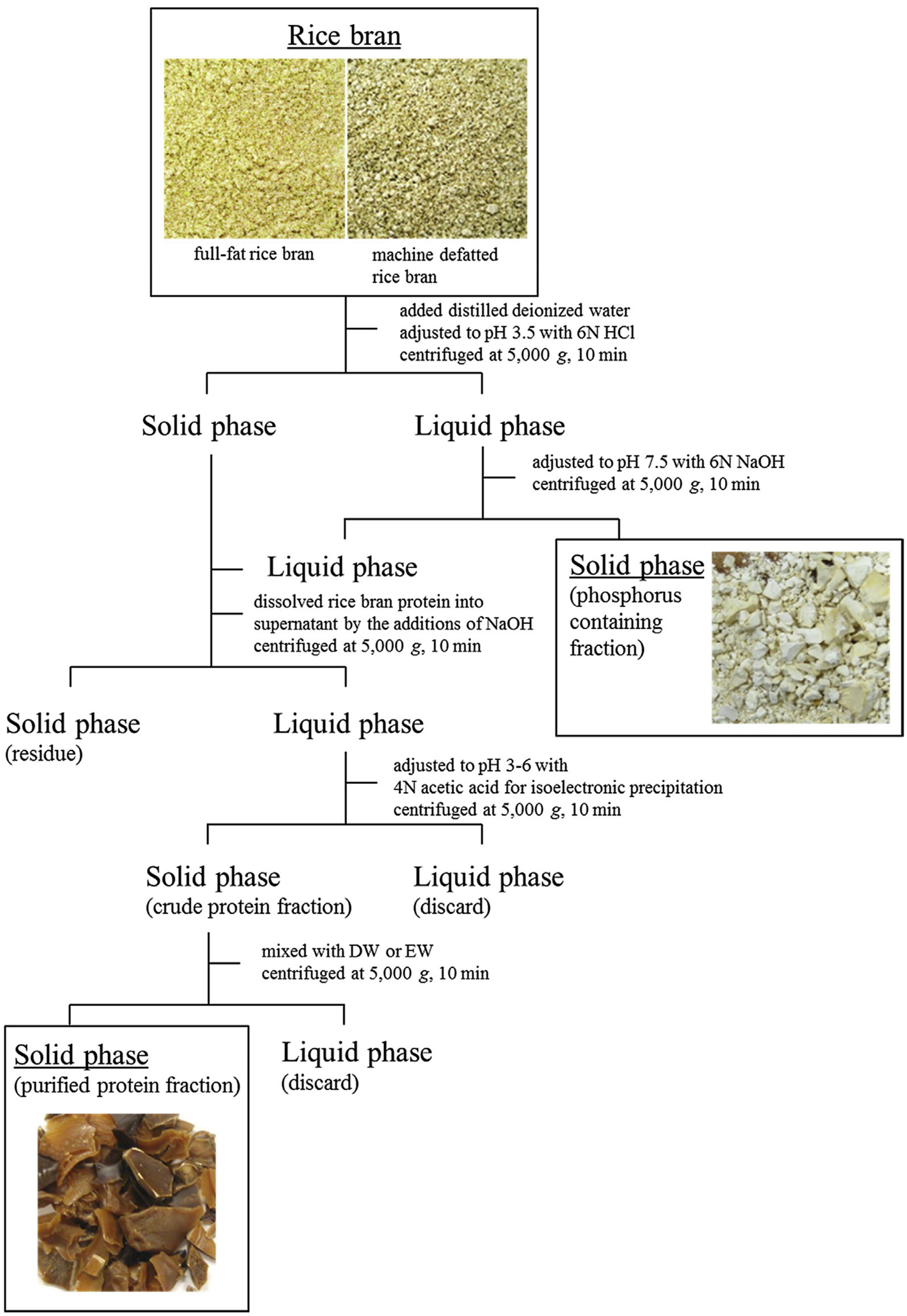

FIG. 1. Flow diagram for recoveries of phosphorus compound and protein concentrates from rice bran.