Comparison of Solvent Extraction Characteristics of Rice Bran Pretreated by Hot Air Drying, Steam Cooking and Extrusion

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Rice bran was pretreated by hot air drying, steam cooking and extrusion before solvent extraction of oil. The extractions were conducted in a glass column percolator (i.d. 120 mm), packed to a depth of 90 cm and using n-hexane at 60 C and gravity feed. Fines (defined as < 0.5 mm) in raw bran were significantly reduced by steam cooking and extrusion treatments. Extruded rice bran (ERB) was pelletized and had a bulk density 1.5 times higher than the other products. Regardless of the weight of bran loaded in the percolator, extraction time to reach 1% residual oil was decreased in the order of 116, 67 and 10 min for hot air-dried rice bran (HARB), steam-cooked rice bran (SRB) and ERB, respectively. This was due to increases in the percolation rate of SRB by 2 times and by 9 times for ERB compared to HARB. The solvent/bran ratio for extraction to 1% residual oil was decreased by nearly half, from 3.18 for HARB and 3.12 for SRB to 1.77 for ERB.

The main problem in producing edible oil from rice bran is rapid development of free fatty acids by lipolytic enzymes. Rice bran is essentially a powder, and problems occur in direct solvent extraction of oil. Fines do not permit rapid solvent percolation under gravity flow, and special pressure techniques are required for effective extraction. Also, the flow of solvent through the bran bed is channelized, resulting in a very high bran/solvent ratio. Removal of solvent retained in the extracted meal is an additional problem (1). Rice bran has been dehydrated as a pretreatment to facilitate solvent extraction in steam-jacketed cylindrical dryers in some plants. However, problems due to fines are not eliminated by this treatment, even though moisture content of the rice bran is 4-6%. Cooking with live steam completely inactivates lipolytic enzymes in the raw rice bran, and causes the particles of bran to adhere to each other, resulting in an improved percolation rate and more efficient oil extraction (2). Extrusion cooking has been considered one of the more promising methods for stabilization, and has been reported to completely inactivate lipase and to agglomerate the bran into larger particles or pellets (3,4).

The present research was conducted to compare the solvent extraction characteristics of rice bran pretreated by hot air drying, steam cooking and extrusion cooking.

MATERIALS AND METHODS

Materials. Fresh rice bran collected at a local mill contained 12.2% moisture and 21.1% oil, and was pretreated as follows. Hot air-dried rice bran (HARB) was prepared by drying the raw bran in a 5-cm layer in a 120 C forced air convection oven for 30 min and cooling to room temperature. Steam-cooked rice bran (SRB) was prepared by cooking with 15 psi live steam in an autoclave for 10 min and drying in a 50 C convection oven for 1 hr. Extrusion-cooked rice bran (ERB) was prepared using a KAIST-Extrusion Rice Bran Stabilizer with 3 dies (3 mm i.d. × 2.5 cm length opening) and 200 kg/hr production rate (3). The raw bran was fed directly into the stabilizer without control of moisture. Our previous results showed that the heat developed was sufficient to achieve an extrusion temperature of 130 C. This is enough to inactivate lipases completely in the raw bran (3). The extruded hot bran was cooled in a sieve plate-air cooler to 40 C. Moisture contents of the sample brans were adjusted to a constant value by conditioning in an atmosphere of 50% relative humidity, and samples were then packed in polyethylene bags to prevent moisture absorption until extraction trials were completed.

Solvent extraction. Extraction was conducted in a glass column percolator (12 cm i.d. × 120 cm long) capped at the botton with a 40-mesh stainless steel screen. The treated samples were poured into the percolator to a depth of 90 cm, and n-hexane was percolated by flooded gravity flow where the bed was maintained at a constant height of 20 cm by adjusting solvent flow rate from a reservoir. Percolator and reservoir solvent temperatures were kept at about 60 C during extraction. The amount of oil extracted at successive time intervals was determined by desolventizing the miscella in a vacuum evaporator. Penetration rate of the solvent through the bran bed during extraction was determined as average cm/min travel for the particular bed depth tested, and percolation rate of miscella through the bran bed under the flooded condition was measured in terms of ml/min/cm^2. After draining free, the miscella retention ratio was calculated by determining the oil and n-hexane which remained in the bed of whole bran. Data reported are averages of three replication trials, unless otherwise specified.

TABLE 1

Moisture and Oil Contents and Bulk Densities of Pretreated Rice Bran[a]

	Pretreated rice bran		
	Hot air-dried	Steam-cooked	Extrusion-cooked
Moisture (%)	6.54	6.81	6.57
Oil (ether extract, %)	22.54	22.43	22.41
Bulk density (g/cc)	0.313	0.333	0.463

[a]Data are the average values of three determinations.

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TABLE 2

Extraction Characteristics of Pretreated Rice Brans[a]

	Pretreated rice bran		
	Hot air-dried	Steam-cooked	Extrusion-cooked
Penetration rate (cm/min)	4.5	5.8	38.0
Percolation rate (ml/cm²/min)	0.784	1.34	7.61
Miscella retention ratio (g miscella/ g inert)	1.30	1.27	0.687
Solvent/bran ratio[b] (kg/kg)	3.18	3.11	1.77

[a]Data are average values of 3 replication trials.
[b]Amount of solvent required per kg pretreated bran to extract the oil to 1% residual oil level.

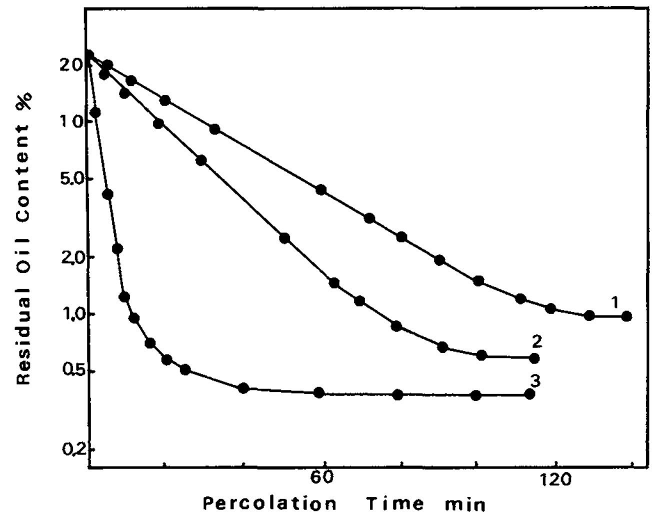

FIG. 1. Extraction curves for solvent extraction of rice brans pretreated by (1) hot air drying, (2) steam cooking, and (3) extrusion.

TABLE 3

Cumulative Particle Size Distribution of Raw and Pretreated Rice Bran[a]

Screen size			Pretreated rice bran		
mesh	(mm)	Raw	Hot air-dried	Steam-cooked	Extrusion-cooked
+ 6	(2.00)	0.16	0.36	0.31	31.50
+ 9	(1.18)	5.87	6.07	8.71	56.85
+32	(0.50)	12.96	13.16	30.42	78.80
+48	(0.30)	31.62	33.82	70.50	97.51
+60	(0.25)	68.79	71.00	95.40	100.00
+100	(0.15)	97.78	97.30	100.00	—
−100		100.00	100.00	—	—

[a]Data are average values of three replication trials.

Analytical methods. Particle size distribution was determined with a Rotap shaker using 6 screens, ranging from 6 mesh (2 mm) to 100 mesh (0.15 mm). After shaking for 15 min, the weight of bran on each screen was determined. Bulk density was determined according to the method described by Narain (5).

RESULTS AND DISCUSSION

Bulk density and particle size. Table 1 shows moisture and oil contents and bulk densities of pretreated rice brans. Moisture contents differed slightly among all pretreated brans, but these differences apparently did not influence extraction characteristics. The physical form of ERB was changed from powder to pellet form, and its bulk density was about one and a half times higher than that of HARB or SRB. HARB was almost the same particle size as raw bran, and contained 86.7% fines (defined as <0.5 mm). The fines decreased to 69.5% and 21.2% in SRB and ERB, respectively (Table 2). Fines did not occur in the ERB during preparation. However, breakage of pellets occurred when ERB was subjected to severe agitation during seiving. Susceptibility to breakage is affected by extrusion conditions (4). Extrusion conditions used for preparation of ERB in this study effectively inactivated lipase and produced pellets with sufficient resistance to breakage during mechanical handling prior to solvent extraction (6).

Extraction characteristics. N-hexane-extractable oil in bran was found to be about 22.4% by complete Soxhlet extraction, as shown in Table 1. Extraction curves obtained in three replication trials for each treated bran are plotted in Figure 1. Three curves are essentially straight lines until the residual oil is reduced to about 1.0%, and then change suddenly. This phenomenon is generally explained on the basis of two different diffusion coefficients, the freed oil and that which must pass through the cell wall (7). The time to reach the residual oil level of 1% was decreased on the order of 116, 67 and 10 min for HARB, SRB and ERB, repsectively. The bed of ERB had enough void volume for the free passage of solvent or miscella through the entire mass of pellets, giving the fastest percolation rate, as shown in Table 3. The miscella volume percolated, however, was not significantly different among all pretreated brans, and ranged between 9.5 and 10.3 l. The percolator used in this study had a bed depth sufficient to allow enough time for solvent to leach the oil or for the oil to combine with the solvent even in the case of ERB. The solvent/bran ratio, defined as the amount of n-hexane required to achieve 1% residual oil level for 1 kg bran, was decreased from 3.18 and 3.11 for HARB and SRB, respectively, to 1.77 for ERB. This result was expected because of significant reduction in the miscella retention ratio for ERB (Table 3). As the bran became wetted with the solvent, the heights of HARB and SRB beds in the percolator were decreased to about 70% of the dry state, resulting in a compact bed which did not allow rapid draining of solvent or miscella.

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