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Evaluation on Quality Indices and Retained Tocopherol Contents in the Production of the Rice-Based Cereal by Extrusion

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ABSTRACT

Rice bran is rich in vitamin E, dietary fiber, mineral and fat. In this study, puffed rice ball was made from brown or milled rice flour by using twin-screw extruder. Two feed moisture (15 and 20%) and two screw speed (200 and 250 rpm) were set, and the physicochemical properties and content of α-, β-, γ-, and δ-tocopherols were determined. The data showed that extrudates made from brown rice had a high a and b value in color, expansion ratio, water solubility index, but low in L value, bulk density and water absorption index than that made from milled rice flour. Extrudates made from brown rice flour had the higher content of α- and γ- tocopherols (4.8 and 5.7 μg/g). Regarding the effects of feed moisture and screw speed of extruder, the data showed that 15% feed moisture in flour and 250 rpm screw speed yielded to a high expansion ratio, high water solubility index, and low bulk density in the final products.

Key words: brown rice, milled rice, twin- screw extruder, physicochemical properties

INTRODUCTION

Brown rice has an outer layer of bran which is rich in minerals, vitamins, protein, fiber and fat(1-2). The hypocholesterolemic effects of rice bran and its fractions have been studied(3-9). In human studies, Hegsted *et al*(10) showed that total cholesterol levels decreased by 7.0% when subjects consumed rice bran product. Rice bran also contains a number of non-fiber constituents in the non-saponifiable oil fraction, which have been implicated as factors in lowering cholesterol, including oryzanol(11).

With the advantages of low capital cost and versatility, extrusion cooking has been widely used to manufacture snacks and breakfast cereals(12). Nonetheless, few references are available on the physical characteristics, the nutritional significance of tocopherol and antioxidative activity in rice-based extruded foods. The objective of this study was to investigate the effect of processing variables (feed moisture content, screw speed) on chemical composition and physical characteristics of extrudates from brown rice flour or milled rice flour.

MATERIALS AND METHODS

I. *Materials*

Brown rice (Tainung sen 19, TNS19), a variety of rice high in amylose content, was obtained from the Taichung District Experimental Station (Taiwan) and was dry- milled to the flour by F200 pin-miller (Yi- Ta, Taiwan). Based on the weight of brown or milled rice flour, sugar (4%), soybean oil (3%) and salt (1.5%) were added.

II. *Extrusion Parameters*

A co-rotating, intermeshing twin screw extruder (TX57, Wenger, USA) with 3.5mm × 0.8mm diameter die was used for extrusion. Tap water was fed to the extruder's first barrel to adjust feed moisture contents at 15 (M15) and 20% (M20) on total weight basis. The barrel temperature profile from feed to die was 80, 100 and 110˚C. Screw speeds were 200 and 250 rpm. The feed rate of each treatment was 60 kg/hr. Extrudates were collected and dried in an air oven at 80˚C for 15 min, and the dried extrudates were vacuum packaged with a OPP/PE/VMPET/PE/CPP bag (Tung-Shi, Taiwan) and kept at room temperature for less than seven days before further analysis.

III. *Color Determination*

The color of the extrudates was determined by a Σ80 Color System (Nippon Deshoku Industry Co., Japan). The L*, a* and b* scales were respectively used as the light to dark, red to blue, and yellow to green indices, respectively.

IV. *Expansion Ratio*

The diameter of 20 extrudates was measured with electronic calipers. The degree of expansion was calculated as the ratio of extrudate diameter to the die diameter(13).

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V. *Bulk Density*

The bulk density of extrudates was measured using the method of Pan *et al*[13]. The volume of the expanded sample was measured with a 100-mL graduated cylinder by rape seed displacement. The volume of 20 g randomized samples was measured for each test. The ratio of sample weight to the replaced volume in the cylinder was calculated as bulk density (w/v).

VI. *Water Absorption Index (WAI) and Water Solubility Index (WSI)*

Water absorption index (WAI) and water solubility index (WSI) were measured according to a modified method of Anderson *et al*[14]. The extrudate was ground to pass through a 60- mesh screen. A 2 g (dry base) ground extrudate sample was mixed with 25 mL of water and put in a centrifuge tube with a vortex mixer. After heating for 30 mins. in a water bath at 30˚C, the heated solution was centrifuged at 3,000 ×g for 10 mins. The WAI and WSI were determined as:

WAI = weight of sediment / weight of dry sample solids;

WSI (%) = (weight of dissolved solids in supernatant / weight of dry sample solids in the original sample) × 100.

VII. *Determination of Tocopherols*

Using a modification of Su's method[15], 10 g of ground extrudate powder (100 mesh) was mixed with 60 mL of 6% pyrogallol in ethanol and 40 mL of 60% KOH solution for 2-3 secs using a vortex mixer, and then heated at 70˚C for 20 min in a water bath. The extraction was conducted using 300 mL of distilled water and n-hexane (1:1 ratio).

The retention times of the reagent grade α-, β-, γ-, and δ-tocopherol standards were 9.28, 14.10, 15.16, and 22.22 mins, respectively. Calibration curves prepared from peak areas and calibration equations of tocopherols were obtained by linear regression analysis that was carried out to measure the chromatographic peaks by comparing the calibration curves. Tocopherols in unsaponified compounds from extrudates were analyzed with an HPLC Model HP11 with UV spectrophotometer detection at 298 nm as the monitor, (HP Co., Ltd., USA), Develosil 60-5 (4.6 × 250 mm) column (Nomura Chemical Co., Ltd., Japan). Mobile phase was n-hexane -dioxane -ethanol (95.8: 4.0: 0.2) at a flow rate of 1.0 mL/min.

VII. *Determination of Thiobarbituric Acid Value (TBA)*

Thiobarbituric acid value (TBA) was measured using a modified method of Yagi[16]. 100 mg of sample was mixed with 50 µL of BHT (4% w/v ethanol), 500 µL of sodium dodecyl sulfate (0.3%), 2 mL of HCl (0.1 N), phosphotungstic acid (10%) and 1 mL of thiobarbituric acid (0.7%). After heating at 100˚C for 45 mins, fluorescent reaction products were assayed on a spectrofluorometer (650-40, Hitachi) with excitation at 532 nm.

IX. *Statistical Analysis*

All data were analyzed using analysis of variance (ANOVA) to detect differences in mean values from triplicate runs of each treatment using Duncan's multiple range test (α = 0.05)[17].

RESULTS AND DISCUSSION

I. *Color Determination*

The data (Table 1) indicated that the high feed moisture resulted in brighter color. Extrudates made from brown rice flour had a low L- value and high a- value. The a- value decreased at high moisture content (20%). In cartradistinction, Phillips *et al*[18] reported that extrudates produced with high feed moisture content obtained a high L* value and low a* value. Extrudates made from brown rice flour had a high b value.

II. *Expansion Ratio and Bulk Density*

Extrudates made from 15% feed moisture content had the high degree of expansion (Table 2). Moisture inversely correlates with expansion ratio for most compositions[19]. Also the expansion ratio increased with increasing feed moisture[13, 20]. A high screw speed (250 rpm) resulted in a higher expansion ratio in high feed moisture. Increasing screw speed increased the expansion ratio[21-23].

Samples in a 15% feed moisture content indicated a low bulk density and high expansion ratio (Table 2). Bulk density decreased with increasing feed moisture up to a certain point and then increased with further moisture increase of defatted soy flour, corn starch and raw beef blends[20]. High feed moisture resulted in a rubbery texture with relatively high bulk density, which was the reason for unable to maintain the product's expanded shape after extrusion[24]. The data also showed that high screw speed (250 rpm) resulted in a low bulk density and high (20%) feed moisture content. In general, bulk density increased with increasing feed moisture or decreasing screw speed[13, 25]. Because the fiber content in brown rice flour (1.02-1.10%) was higher than that in milled rice flour (0.30-0.34%), the bulk density of the products (M15S200, M20S200 and M20S250) decreased with increased brown rice flour content ($p<0.05$). Camine and King reported similar findings that 10% soy fiber reduced bulk density for extruded cornmeal snack[26].

III. *Water Absorption Index (WAI) and Water Solubility Index (WSI)*

Extrudates obtained from low feed moisture and high screw speed had the lowest water absorption index (WAI)

Table 1. Effect of feed moisture and screw speed on color of extruded brown rice flour and milled rice flour[a]

	L			
Extrudates[c]	M15S200[b]	M15S250	M20S200	M20S250
Brown rice	76.01bz[d]	75.73bz	79.67az	79.30az
Milled rice	82.01by	82.08by	84.19ay	84.29ay
	a			
Extrudates	M15S200	M15S250	M20S200	M20S250
Brown rice	9.45ay	9.41ay	4.84by	4.85by
Milled rice	8.25az	8.21az	4.15bz	4.20bz
	b			
Extrudates	M15S200	M15S250	M20S200	M20S250
Brown rice	17.76by	17.54by	17.16cy	18.28ay
Milled rice	12.07bz	11.89bz	15.87az	15.78az

a: Mean of the triplicate results.
b: M15S200: Feed moisture 15%, screw speed 200rpm; M15S250: Feed moisture 15%, screw speed 250rpm;
M20S200: Feed moisture 20%, screw speed 200rpm; M20S250: Feed moisture 20%, screw speed 250rpm.
c: Brown rice: Extrudates made from 100% brown rice flour; Milled rice: Extrudates made from 100% milled rice flour.
d: Means within the same row (a-c) or column with different letters (y-z) are significantly different ($p<0.05$).

Table 2. Effect of feed moisture and screw speed on expansion ratio and bulk density of extruded brown rice flour and milled rice flour[a]

	Expansion Ratio			
Extrudates[c]	M15S200[b]	M15S250	M20S200	M20S250
Brown rice	6.05by[d]	6.75ay	3.00dy	5.15cy
Milled rice	5.88ay	6.25ay	2.70cy	4.50bz
	Bulk Density (g/cm^3)			
Extrudates	M15S200	M15S250	M20S200	M20S250
Brown rice	0.058cz	0.052dy	0.383az	0.128bz
Milled rice	0.068cy	0.059cy	0.435ay	0.240by

a: Mean of the triplicate results.
b: M15S200: Feed moisture 15%, screw speed 200rpm; M15S250: Feed moisture 15%, screw speed 250rpm;
M20S200: Feed moisture 20%, screw speed 200rpm; M20S250: Feed moisture 20%, screw speed 250rpm.
c: Brown rice: Extrudates made from 100% brown rice flour; Milled rice: Extrudates made from 100% milled rice flour.
d: Means within the same row (a-d) or column with different letters (y-z) are significantly different ($p<0.05$).

Table 3. Effect of feed moisture and screw speed on water absorption index (WAI) and water solubility index (WSI) of extruded brown rice flour and milled rice flour[a]

	WAI			
Extrudates[c]	M15S200[b]	M15S250	M20S200	M20S250
Brown rice	2.51cz[d]	2.35dy	12.79az	9.94bz
Milled rice	2.82cy	2.62cy	14.06ay	10.89by
	WSI(%)			
Extrudates	M15S200	M15S250	M20S200	M20S250
Brown rice	68.58by	73.02ay	17.84dy	23.22cy
Milled rice	66.23bz	70.07az	16.20dz	21.13cz

a: Mean of the triplicate results.
b: M15S200: Feed moisture 15%, screw speed 200 rpm; M15S250: Feed moisture 15%, screw speed 250 rpm;
M20S200: Feed moisture 20%, screw speed 200 rpm; M20S250: Feed moisture 20%, screw speed 250 rpm.
c: Brown rice: Extrudates made from 100% brown rice flour; Milled rice: Extrudates made from 100% milled rice flour.
d: Means within the same row (a-d) or column with different letters (y-z) are significantly different ($p<0.05$).

and lowest water solubility index (WSI) (Table 3). A high screw speed indicated a short residence time of starch in the barrel and resulted in lower water absorption[(13)]. Also, low feed moisture content showed a very low WAI, but high WSI ($p<0.05$). Jean et al. reported that extruded potato and chicken meat at low feed moisture content had higher compressive resistance and solubility[(27)]. The solubility increased in extrudate with decreasing feed moisture during extrusing of corn meal[(28-29)]. WSI increased with increasing screw speed for both feed moisture levels. Extrudates made from brown rice had a low WAI and a high WSI than that made from milled rice flour. Therefore, selecting a low feed moisture and high screw speed will give a high water solubility index of this brown rice product.

IV. *Determination of Tocopherols*

Brown rice flour had higher vitamin E content than milled rice flour. Tocopherol contents in extrudates remained relatively high (Table 4). Our study showed extrudate made from brown rice flour had the higher content of α- and γ-tocopherols (4.8 and 5.7 μg/g). We believe the increase in tocopherol concentration of the extrudates was due to soybean oil. It has been reported that soybean oil could give 1100 ppm total tocopherol and the composition of α-, β-, γ-, and δ- tocopherols were 4.0, 1.1, 67.1 and 28.8%, respectively[30]. In our experiment, the soybean oil in the extrudate consisted of 65.0 μg/g α-, 15.0 μg/g β-, 654.5 μg/g γ- and 265.5 μg/g δ-tocopherols. So 1 g of extrudate obtained ideal 2.0 μg/g α-, 0.5 μg/g β-, 19.6 μg/g γ- and 8.0 μg/g δ-tocopherols from external 3% soybean oil. However, the content of tocopherols was not too high. The reason is that heating caused oxidation or degradation of tocopherols and decreased the concentration of tocopherols after extrusion.

V. *Determination of Thiobarbituric Acid Value (TBA)*

TBA values of extrudates of both rice samples increased with increasing storage time ($p<0.05$) (Table 5). Furthermore, the data showed there was no significant difference between extrudates of brown rice and milled rice within 6 storage months. We think the TBA values of brown rice extrudates were not higher than those of milled rice extrudates because brown rice extrudates has higher tocopherol concentration until the 6th month. However, the TBA values of brown rice extrudates were higher than those of milled rice extrudates at the 9th and 12th storage month. This may be correlated to the decreased tocopherol concentration of extrudates and their lipid contents which were 1.95-1.98% and 0.79-0.88% for brown rice extrudates and milled rice extrudates, respectively. In the future, perhaps some antioxidant shoulded be added to the extrudate to avoid oxidation of lipid.

Table 4. Tocopherol content (μg/g) of extruded brown rice flour and milled rice flour and raw materials[a]

		Tocopherol Content (μg/g)			
		α	β	γ	δ
Raw materials	Brown rice flour	3.7	–	4.4	–
	Milled rice flour	1.6	–	1.2	–
Extrudates[b]	Brown rice	4.8	1.5	5.7	4.0
	Milled rice	2.0	–	1.4	1.1

a: Mean of the triplicate results.
b: Brown rice: Extrudates made from 100% brown rice flour; Milled rice: Extrudates made from 100% milled rice flour.

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Table 5. Thiobarbituric acid value (TBA) of extruded brown rice flour and milled rice flour[a]

	TBA				
Extrudates [b]	0	3	6	9	12 months
Brown rice	0.082ey[c]	0.189dy	0.252cy	0.373by	0.405ay
Milled rice	0.080ey	0.191dy	0.242cy	0.359bz	0.387az

a: Mean of the triplicate results.
b: Brown rice: Extrudates made from 100% brown rice flour; Milled rice: Extrudates made from 100% milled rice flour.
c: Means within the same row (a-e) or column with different letters (y-z) are significantly different ($p<0.05$).

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擠壓米產品之品質指標及生育醇含量評估

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摘　　要

米糠是糙米的最外層含有豐富的維生素E、膳食纖維、礦物質及油脂，本研究即利用糙米或精白米為主原料，經由雙軸擠壓機製造膨發休閒食品，其原料水分分別為15及20%，螺軸轉速為200及250 rpm，進行探討產品理化特性以求得最適加工條件，並進一步分析生育醇之殘存量。結果顯示，含糙米之擠壓食品在顏色分析上有較高之a、b值，膨發度及溶解度亦較由精白米製造之擠壓食品高；相反的，L值、表密度及吸水性指標則較低，且由糙米製造得到之擠壓食品有較高之α-及γ-生育醇含量(4.8及5.7 μg/g)。由15%原料水分及250 rpm螺軸轉速會得到膨發度與溶解度較高及表密度較低之產品。

關鍵詞：糙米，精白米，雙軸擠壓機，理化特性