

Functional Properties and Utilization of Rice Bran Dietary Fiber in Bread สมบัติเชิงหน้าที่และการประยุกต์ใช้ใยอาหารจากรำข้าวในขนมปัง

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บทคัดย่อ

รำข้าว เป็นผลพลอยได้จากการขัดสีข้าวซึ่งมีใยอาหารสูง วัตถุประสงค์ในงานวิจัยครั้งนี้เพื่อศึกษาสมบัติเชิงหน้าที่ของเส้นใยอาหารจากรำข้าว และประยุกต์ใช้ในผลิตภัณฑ์ขนมปัง พบว่าเส้นใยอาหารจากรำข้าวมีความสามารถในการกักเก็บน้ำ ความสามารถในการอุ้มน้ำ ความสามารถในการพองตัว มีค่า 16.4, 15.5 และ 10.1 กรัม/น้ำต่อกรัมตัวอย่าง ตามลำดับ สำหรับความสามารถในการจับกับไขมัน มีค่า 3.26 กรัมไขมันต่อกรัมตัวอย่าง ดังนั้นสมบัติเชิงหน้าที่ของเส้นใยอาหารจากรำข้าวจึงมีศักยภาพในการประยุกต์ใช้ในผลิตภัณฑ์อาหาร เมื่อนำเส้นใยอาหารจากรำข้าวชนิดหยาบไปประยุกต์ใช้ในผลิตภัณฑ์ขนมปังที่ระดับความเข้มข้นแตกต่างกัน คือร้อยละ 0, 1, 3 และ 5 พบว่ามีผลต่อการเปลี่ยนแปลงสมบัติทางเคมีและกายภาพของโดและขนมปัง โดยความเข้มข้นของเส้นใยอาหารที่ระดับความเข้มข้นร้อยละ 1 จะมีผลต่อปริมาตรก้อนขนมปัง ปริมาตรจำเพาะของขนมปัง (Specific volume) ความนุ่ม (Crumb softness) และความสามารถในการกักเก็บก๊าซ (Gas retention) ไม่แตกต่างกับตัวอย่างควบคุม (ไม่ใส่เส้นใยอาหาร) ($P>0.05$) ในทางตรงข้ามการเติมเส้นใยอาหารที่ระดับความเข้มข้นเพิ่มขึ้นส่งผลให้สมบัติต่างๆ ลดลงแตกต่างกับตัวอย่างควบคุมอย่างมีนัยสำคัญทางสถิติ ($P<0.05$) สำหรับปริมาณความชื้นและเส้นใยอาหารจะแปรผันตามปริมาณเส้นใยอาหารที่เติมลงในขนมปัง ส่วนการยอมรับทางประสาทสัมผัสของผู้บริโภค (ลักษณะปรากฏ สี กลิ่น รสชาติ ลักษณะเนื้อสัมผัส และความชอบโดยรวม) พบว่าตัวอย่างขนมปังที่เติมเส้นใยอาหารที่ระดับความเข้มข้นร้อยละ 1 ผู้บริโภคให้คะแนนการยอมรับทางประสาทสัมผัสไม่แตกต่างจากตัวอย่างควบคุม ผลจากงานวิจัยนี้สามารถใช้เป็นข้อมูลและความรู้พื้นฐานในการประยุกต์ใช้เส้นใยอาหารจากรำข้าวในผลิตภัณฑ์ต่างๆ

คำสำคัญ: รำข้าว เส้นใยอาหาร สมบัติเชิงหน้าที่ ขนมปัง

Abstract

Rice bran is the major by-product generated during the first step of milling and is composed of high dietary fiber. The objective of this research aimed to determine the functional properties of dietary fiber from rice bran and apply dietary fiber into bread products to improve the quality and consumer acceptance. The water-retention capacity, water-holding capacity, and swelling capacity of dietary fiber from rice bran were 16.4, 15.5 and 10.1 g water/g sample respectively, and the fat-binding capacity of dietary fiber was 3.26 g oil/g sample. Therefore, dietary fiber from rice bran has good potential in various food products due to its functional properties. When incorporating 0, 1, 3, and 5% of dietary fiber in bread, the loaf weight was the same as the control. The loaf volume, specific volume, and gas retention decreased compared to those of the control sample. In contrast, hardness increased compared to those of the control sample. Adding 1% of dietary fiber gave the same physical properties as the control. The higher fiber and moisture content in bread corresponded to the amount of dietary fiber added. However,

results from sensory evaluation showed that the addition of more than 1% dietary fiber decreased liking scores in all attributes (appearance, color, odor, taste, texture, and overall). The results of this study could be used in the basic knowledge of rice bran utilization in other food products.

Keywords: Rice bran; Dietary fiber; Functional properties; Bread

Introduction

Rice bran, a by-product of the rice milling process, contains a number of valuable components such as proteins, lipids, carbohydrates, dietary fibers, vitamins, and minerals that exhibit health benefits [1],[2]. Currently, a large amount of rice bran is discarded and used as animal feed [3]. The defatted residues of bran contain 15.4% protein, especially in lysine content higher than rice endosperm protein or any other cereal proteins [4],[5], and the rice bran generated during the first step of milling has high dietary fiber.

Dietary fiber has been shown to have important health implications in the prevention risk of chronic diseases such as cancer, cardiovascular diseases, and diabetes mellitus [6],[7]. It comes from the family of carbohydrates, a non-starch polysaccharide, not digested in the small intestine but may be fermented in the colon into short chain fatty acids (SCFA). It enhances water absorption in the colon, thus preventing constipation. Dietary fiber has the ability to bind with bile acids and prevents its re-absorption in the liver, thus inhibiting cholesterol synthesis. Its viscous and fibrous structure can control the release of glucose with time in the blood, thus helping in the proper control and management of diabetes mellitus and obesity [8],[9],[10]. Therefore, rice bran may have potential as a good source of ingredients in the food industry. The development of new food items from rice by-products calls for the most precise information

obtainable on desirable and undesirable components [4]. This current study aimed to investigate the functional properties of dietary fiber from rice bran, study changes occurring in breads that use it, and determine consumer acceptance of these breads.

Materials and Methods

1. Raw Materials

Rice bran (Khao Dawk Mali 105) was generated during the first step (Rice bran 1st step) and second step (Full fat rice bran) of milling and obtained from a local milling factory in Warinchamrap, Ubon Ratchathani, Thailand. Defatted rice bran was a by-product from the rice bran oil production process and obtained from a local rice bran oil factory in Sumrong, Ubon Ratchathani, Thailand.

2. Chemical composition analysis

Moisture, ash, protein, lipid, and fiber of rice bran were determined according to the method of AOAC [11].

3. Preparation of dietary fiber

Total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) were prepared according to the method of AOAC enzymatic-gravimetric [11] with slight modifications. Rice bran was gelatinized with termamyl (heat stable alpha-amylase) at 95-100°C for 30 min and then digested with protease (60°C, 30 min), followed by incubation with amyloglucosidase (60°C, 30 min) to remove protein and starch. Four volumes of 95% ethanol

(preheated to 60°C) were then added to precipitate soluble dietary fiber. Precipitation was allowed to form at room temperature for 60 min, followed by filtration. The residue was then washed with 78% ethanol, 95% ethanol, and acetone. The residue was then oven-dried at 105°C overnight in an air oven and then weighed.

Values obtained by the enzymatic method were then corrected by analyzing for nitrogen by the Kjeldahl method and ashing at 525°C.

$$\text{WHC (g/g)} = \frac{\text{Residue hydrated weight} - \text{Residue dry weight}}{\text{Residue dry weight}}$$

4.2 Water-retention capacity

Water-retention capacity (WRC) defined as the quantity of water that remains bound to the hydrated fiber following the application of the external force (pressure of centrifugation) was determined by accurately weighing a dry sample into a graduated test tube, adding 30 ml of water,

$$\text{WRC (g/g)} = \frac{\text{Residue hydrated weight} - \text{Residue dry weight (After centrifugation)}}{\text{Residue dry weight}}$$

4.3 Swelling capacity

Swelling capacity (SC) is defined as the ratio of the volume occupied when the sample is immersed in excess of water after equilibration to the actual weight. An accurately weighed dry sample was placed in a graduated test tube, around 10 ml of water was added and it was hydrated for 18 h, and the final volume attained by the sample was measured [12].

$$\text{SW (ml/g)} = \frac{\text{Volume occupied by sample}}{\text{Original sample weight}}$$

4. Functional properties of dietary fiber from rice bran

4.1 Water-holding capacity

Water-holding capacity (WHC) defined as the quantity of water that is bound to the fiber without the application of any external force was determined by accurately weighing a dry sample into a graduated test tube, and adding around 30 ml of water, and hydrating it for 18 h at an ambient temperature. The supernatant was removed. The hydrated residue weight was recorded and it was dried at 105°C for 2 h to obtain the residue dry sample [12].

and hydrating it for 18 h. It was then centrifuged (3000 g, 20 min) and the supernatant solution was removed. The hydrated residue weight was recorded and the sample was dried at 105°C for 2 h to obtain its dry weight [12].

4.4 Fat-binding capacity

The fat-binding capacity (FBC) of dietary fiber from rice bran was determined [13]. A four gram of sample was added to 20 ml of corn oil in a 50 ml centrifuge tube. The content was then stirred for 30 s every 5 min and, after 30 min, the tubes were centrifuged at 1600 g for 25 min. The free oil was then decanted and the absorbed oil wad was then determined by the difference. The fat-binding capacity was expressed as absorbed oil per gram sample.

4.5 Emulsifying capacity

Emulsifying capacity (EC) was measured [13]. Twenty milliliters of 7% aqueous dispersion of the fiber was mixed with 20 ml corn oil and blended in a Warning blender for 5 min at high speed. An aliquot was then centrifuged at 3000 g for 5 min. The percentage of total mixture that remained emulsified after centrifugation was expressed as the stability index. The stability index of a good emulsion should be greater than 94%, while that of a poor emulsion should be 50%.

5. Preparation of Bread

Ingredients for making bread of a control and rice bran dietary fiber added bread are wheat flour, salt, sugar, yeast, butter, and water. Dietary fiber from rice bran was used to substitute wheat flour (0, 1, 3 and 5%) and other ingredients were kept constant for all formulae.

For bread preparation, the procedures were mixing wheat flour and yeast then pass through sieve 100 mesh before adding dietary fiber. In the meantime, sugar, salt, and water were added in another bowl and mixed well. The ingredients were poured together and mixed well (~10 min). Butter was added and kneaded to form dough until it was smooth and elastic (~7 min). The dough was left at an ambient temperature for 10 min, then placed in a 1 lb rectangular bowl and left for another 180 min in an incubator. The bowl was placed in an oven set at 190-200°C for 35 min or until the surface turns yellow. The product was taken out from an oven and left to cool before further analysis.

6. Analytical methods of bread

Gas retention, loaf weight, loaf volume, and specific volume of bread were determined [14]. The color of the bread was determined using

a Hunter Lab (Color Flex Model 45/0, USA). Five measurements from the crusts and crumbs of each loaf were taken. The texture of the bread was evaluated in terms of TPA by Texture analyzer (LLOYD texture analyzer model LRSK, UK). The bread was compressed at a test speed 60 mm/min by a compression plate 50x50 mm until reaching a compression ratio of 75%. Measurements were taken five times. The proximate analysis of bread was determined according to the method of AOAC [11].

The sensory evaluation of the bread was conducted by 40 panelists who were students or staff members in the Department of Agro-Industry, Ubon Ratchathani University. Randomly-coded samples were served to panelists individually. Six sensory attributes were evaluated (appearance, color, odor, taste, texture, and overall acceptance) using a 9-point hedonic scale for each trait, where 9 = excellent and 1 = extremely poor.

The surface and cross-section microstructure of dried crumbs were observed using a scanning electron microscopy analyzer. Samples were coated with gold using a sputter coater, model SPI-MODULE™ Sputter Coat, and examined by a JEOL, JSM-5410LV scanning microscope.

2.7 Data analysis

All experiments and analytical measurements were run in triplicate. Means of each parameter were analyzed by analysis of variance (ANOVA). Differences between treatments at the 5% ($p \leq 0.05$) level were considered significant.

Results and discussion

1. Chemical compositions

Chemical compositions of full fat rice bran, defatted rice bran and rice bran from the first step of milling are shown in Table 1. Full fat rice bran was composed of 11.09% protein and 17.32% fat. After a defatting process, the fat

content reduced from 17.32% to 1.85% (approximately 90% reduction). Crude fiber content of full fat rice bran and defatted rice bran was 5.78-5.85%. In contrast, rice bran from the first step of milling contained high fiber (41%). This research chose rice bran from the first step of milling for further analysis.

Table 1 Chemical compositions of full fat rice bran, defatted rice bran and rice bran from the first step milling

Compositions (%)	Full fat rice bran	Defatted rice bran	Rice bran (1 st step)
Moisture	9.97±0.04	8.48±0.03	8.91±0.31
Protein	11.09±0.43	14.32±0.46	3.83±0.07
Fat	17.32±0.31	1.85±0.19	1.83±0.02
Crude fiber	5.85±0.61	5.78±0.24	41.02±0.46
Ash	6.34±0.11	10.23±0.07	8.74±0.09
Carbohydrate	49.42	59.34	35.66

Values are given as mean ± standard deviation from triplicate determination

2. Dietary fiber

Total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) of rice bran were 60.92, 0.002, and 60.69% respectively. The total dietary fiber of rice bran was reported as 53.25% [15] while the total dietary fiber of defatted rice bran was reported as 27.04% [13] and the total dietary fiber of cereals was reported as 97% [16]. Results indicated that rice bran from the first step of milling contained high dietary fiber.

major changes that occur during baking, which include starch gelatinization, protein denaturation, yeast and enzyme inactivation, and flavor and color formation [13]. A high water absorption of dietary fiber helps to reduce moisture loss in packed bakery products. Also it is required to maintain freshness and a moist mouth feel of baked foods [14]. It indicates that dietary fiber processes good WRC, WHC, and SC and can be used in products requiring high water retention. Results obtained in this work were similar to or even higher than those reported for most described by-product fibers, for example, 5.18-8.08 g water/g sample for peel fiber from citrus [17], 4.89 and 4.56 g water/g sample for dietary fiber from defatted rice bran and FIBREX [13]. The high WRC, WHC, and SC of dietary fiber showed that this material could be use as a functional ingredient to avoid syneresis,

3. Functional properties of dietary fiber from rice bran

Water-retention capacity (WRC), water-holding capacity (WHC), and swelling capacity (SC) of dietary fiber from rice bran were 16.04 g water/g of sample, 15.50 g water/g of sample, and 10.10 ml water/g of sample respectively (Table 2). Water plays an important role in the

modification of texture and viscosity, and reduce calories of food formulations [17]. Besides, fat-binding capacity (FBC) and emulsifying capacity (EC) of dietary fiber from rice bran were 3.07 ml oil/g of sample and 6.90% respectively (Table 2). High oil absorption is essential in the formulation

of food systems like sausages, cake batters, mayonnaise, and salad dressings. Then dietary fiber from rice bran was not a good emulsifier, causing an emulsifying capacity of less than 50% [13].

Table 2 Functional properties of dietary fiber from rice bran

Functional properties	Dietary fiber
Water retention capacity: WRC (g water/g of sample)	16.40±1.98
Water holding capacity: WHC (g water/g of sample)	15.50±1.11
Swelling capacity: SC (ml water/g of sample)	10.10±0.25
Fat binding capacity: FBC (ml oil/g of sample)	3.26±0.03
Emulsifying capacity (%EC)	8.13±2.09

Values are given as mean ± standard deviation from triplicate determination

4. Application of dietary fiber from rice bran in bread

Four bread samples were prepared by substituting wheat flour with 0, 1, 3, and 5% dietary fiber from rice bran. The result of the gas retention experiment is shown in Fig.1. For this experiment, we observed the highest gas retention of all samples during dough-proofing at 180 min. The increase in dietary fiber resulted in a decrease in gas retention. All dietary fiber added breads had significantly lower loaf volume and firmer texture than the control bread (no added dietary fiber) (Table 3). It suggested that dietary fiber reduces loaf volume by diluting

gluten content and changing crumb structures, which in turn impairs CO₂ retention [14]. Darkness of the crumb and crust was directly related to increased dietary fiber content (Table 4). The proximate analyses of control and dietary fiber added breads are shown in Table 5. The protein of all samples was not significantly different. On the other hand, each sample contained statistically different amounts of moisture, fat, dietary fiber, and ash. The moisture content as well as dietary fiber content of bread increased as the amount of dietary fiber added increased. Then rice bran was a good source of fiber [13].

Table 3 Effect of dietary fiber from rice bran on physical properties of bread

Dietary fiber (%)	Loaf weight (g)	Loaf volume (ml)	Specific volume (ml/g)	Hardness (N)
0	42.04±1.14 ^a	600.00±0.00 ^a	14.28±0.49 ^a	2.57±0.09 ^c
1	41.06±3.55 ^a	593.33±11.54 ^a	14.51±1.02 ^a	2.76±0.11 ^c
3	41.84±2.12 ^a	526.67±10.00 ^b	12.58±0.15 ^b	3.87±0.44 ^b
5	43.28±0.92 ^b	483.33±5.77 ^c	11.17±0.37 ^c	4.21±0.05 ^a

^{a,b,c} Values with different letters in the same column are significantly different ($p \leq 0.05$)

Means \pm SD, each value in the table is the mean of three replications and five replications for hardness

Table 4 Effect of dietary fiber from rice bran on color of bread

Dietary fiber (%)	Crust			Crumb		
	L*	a*	b*	L*	b*	L*/b*
0	72.84±2.04 ^a	4.15±0.56 ^c	27.93±1.61 ^a	78.93±1.22 ^a	10.11±0.12 ^d	7.81±0.07 ^a
1	70.31±2.74 ^a	3.17±0.66 ^d	26.73±1.25 ^a	74.64±1.47 ^b	11.52±0.10 ^c	6.48±0.03 ^b
3	65.25±3.60 ^b	5.60±0.82 ^b	27.67±1.58 ^a	72.25±0.83 ^c	14.14±0.05 ^b	5.11±0.14 ^c
5	61.78±3.74 ^c	6.64±0.78 ^a	29.38±1.63 ^a	67.89±0.16 ^d	15.85±1.37 ^a	4.28±0.18 ^d

^{a,b,c,d} Values with different letters in the same column are significantly different ($p \leq 0.05$)

Means \pm SD, each value in the table is the mean of five replications

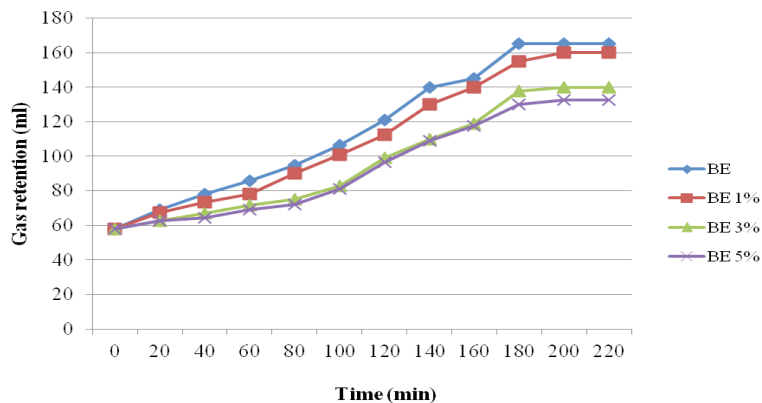


Figure 1 Effect of dietary fiber from rice bran on gas retention capacity of bread dough

BE: bread control (0%) BE1%: 1% dietary fiber BE3%: 3% dietary fiber BE5%: 5% dietary fiber

Sensory evaluation results are shown in Table 6. Generally, all the samples were found acceptable to the panelists. Hedonic scores of appearance, odor, taste, texture, and overall

acceptance for 1% dietary fiber added bread were not different from the control (no added dietary fiber), but there were significantly lower scores on color. The hedonic scores of all attributes for 3 and 5%

dietary fiber added bread were significantly lower when compared with the control. The darker color and unfamiliar taste to panelists of some treated samples could be contributed to lower hedonic scores when compared with the control bread. All dietary fiber added breads had significantly firmer texture than the control bread. Despite this result, the panelists still preferred the lighter color and softer texture of bread containing dietary fiber. From the

sensory result, it can be concluded that adding 1% dietary fiber is accepted by consumers.

The scanning electron microscope photograph of the control and dietary fiber added breads were compared (Fig. 2). The number of crumb cells reduced after the addition of dietary fiber. The decreased number of cells in the dietary fiber added bread was reflected in terms of lower loaf volume and specific volume which, in turn, had significant relation to crumb softness [3],[13].

Table 5 Proximate analysis of bread

Proximate analysis (%)	Dietary fiber (%)			
	0	1	3	5
Moisture	33.37±2.07 ^b	35.14±0.28 ^a	35.28±0.01 ^a	35.80±0.77 ^a
Protein	14.65±0.19 ^a	14.24±0.21 ^a	14.48±0.19 ^a	13.99±0.03 ^a
Fat	0.98±0.07 ^b	1.10±0.05 ^b	1.24±0.02 ^a	1.30±0.12 ^a
Dietary fiber	0.97±0.01 ^d	1.50±0.05 ^c	3.11±0.01 ^b	4.50±0.32 ^a
Ash	0.85±0.01 ^d	0.92±0.00 ^c	1.06±0.01 ^b	1.21±0.01 ^a

^{a,b,c,d} Values with different letters in the same row are significantly different ($p \leq 0.05$)

Means \pm SD, each value in the table is the mean of three replications

Table 6 Effect of dietary fiber from rice bran on sensory evaluation of bread

Dietary fiber (%)	Appearance	Color	Odor	Taste	Texture	Overall acceptance
0	7.28±1.58 ^a	7.28±1.33 ^a	6.90±1.35 ^a	6.70±1.68 ^a	7.03±1.84 ^a	6.93±1.77 ^a
1	7.05±1.29 ^a	6.55±1.35 ^b	6.63±1.64 ^{ab}	6.55±1.73 ^{ab}	6.53±1.46 ^a	6.65±1.46 ^{ab}
3	6.78±1.38 ^a	6.55±1.51 ^b	6.30±1.65 ^{ab}	5.88±1.57 ^{bc}	5.68±1.96 ^b	6.60±1.70 ^{ab}
5	5.98±1.52 ^b	5.90±1.51 ^c	6.03±1.65 ^b	5.38±1.66 ^c	4.88±1.77 ^c	5.95±1.29 ^b

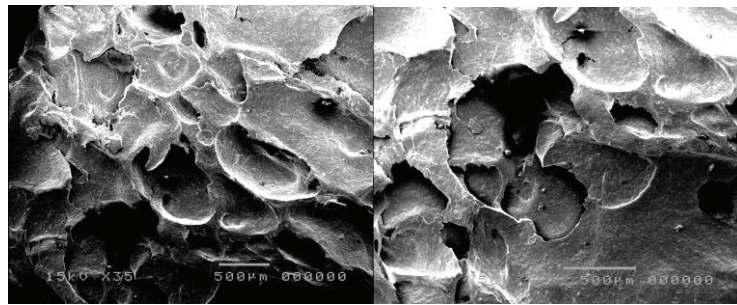
^{a,b,c} Values with different letters in the same column are significantly different ($p \leq 0.05$)

Mean values based on a 9-point scale where 1=extremely poor and 9=excellent

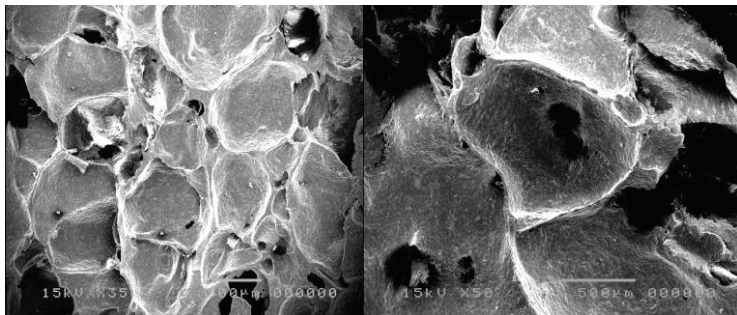
Conclusion

The study showed that dietary fiber from rice bran had a good water-retention capacity, water-holding capacity, and swelling capacity, and that it can be used in products requiring high water retention. The addition of dietary fiber from rice bran to bread significantly affected some bread qualities.

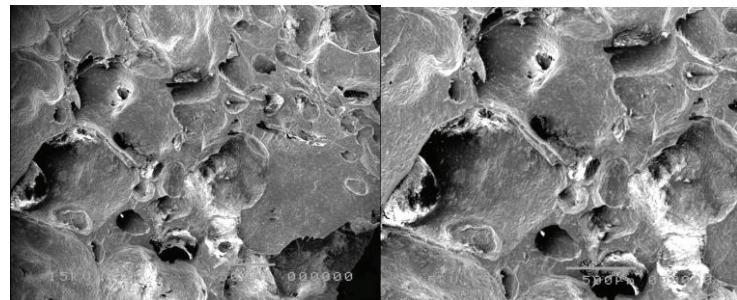
Increasing addition of dietary fiber decreased the loaf volume, specific volume, crumb softness, and overall sensory acceptance of bread. However, the sensory attributes of 1% dietary fiber added bread was found to be similar to the control bread. Therefore, dietary fiber from rice bran could be used as a functional ingredient in other food products.



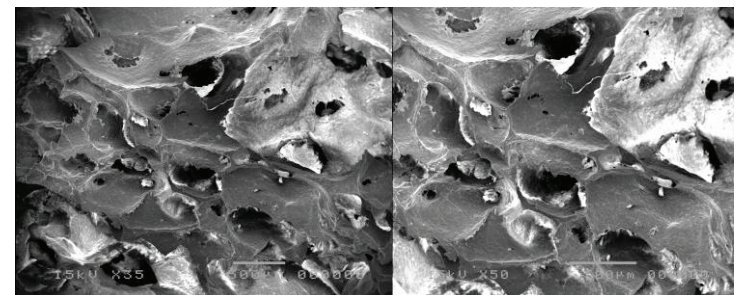
(A) control bread (no added dietary fiber)



(B) 1% dietary fiber added bread



(C) 3% dietary fiber added bread



(D) 5% dietary fiber added bread

Figure 2 Electron microscope photograph of control (A) and dietary fiber added breads (B, C and D)

References

- [1] Saunder, R.M. 1990. "The properties of rice bran as a food stuff." **Cereal Foods World**. 35: 632-662.
- [2] Fabian, C.; Ayucitra, A.; Ismadji, S. and Ju, Y. 2011. "Isolation and characterization of starch from defatted rice bran." **Journal of the Taiwan Institute of Chemical Engineers**. 42: 86-91.
- [3] Hu, G., Huang, S., Cao, S. and Ma., Z. 2009. "Effect of enrichment with hemicellulose from rice bran on chemical and functional properties of bread." **Food Chemistry**. 115: 839 – 842.
- [4] Chandī, G.K. and Sogi, D.S. 2007. "Functionnal properties of rice bran protein concentrates. *Journal of Food Engineering*. 79 (2): 592-597.
- [5] Juliano, B.O. 1985. **Rice Chemistry and Technology**. St. Paul, MN.: American Association of Cereal Chemists.
- [6] Rodriguez, R.; Jimenez, A.; Bolanos, J.F.; Guillen, R. and Heredia, A. 2006. "Dietary fibre from vegetable products as source of functional ingredients." **Trend in Food Science & Technology**. 17: 3-15.
- [7] Brownlee, I.A. 2011. "The physiological roles of dietary fiber." **Food Hydrocolloids**. 25: 238-250.
- [8] Larrauri, J.A. 1999. "New approaches in the preparation of high dietary fibre powders from fruit by-product." **Trends in Food Science & Technology**. 10: 3-8.
- [9] Trinidad, T.P., Mallilin, A.C., Valdez, D.H., Loyola, A.S., Askali-Mercado,F., Castillo, J.C., Encabo, R.R., Masa, D.B., Maglaya, A.S. and Chua, M.T. 2006. "Dietary fiber from coconut flour: a functional food." **Innovative Food Science and Emerging Technologies**. 7: 309-317.
- [10] Phillips, G.O. 2011. "An introduction: Evolution and finalization of the regulatory definition of dietary." **Food Hydrocolloids**. 25:139-143.
- [11] A.O.A.C. 1995. **Official Methods of Association of Analytical Chemists**. 16th ed. Association of Analytical Chemists, Washington D.C.
- [12] Sowbhagya, H.B., Suma, P., Mahadevamma, S. and Tharanathan, R.N. 2007. "Spent residue from cumin – a potential source of dietary fiber." **Food Chemistry**. 104: 1220 – 1225.
- [13] Abdul – Hamid, A. and Luan, Y. W. 2000. "Functional properties of dietary fibre prepared from defatted rice bran." **Food Chemistry**. 68: 15 – 19.
- [14] Shittu. T.A., Aminu, R.A. and Abulude, E.O. 2009. "Functional effects of xanthan gum on composite cassava-wheat dough and bread." **Food Hydrocolloids**. 23: 2254-2260.
- [15] Choi, Y., Choi, J., Han, D., Kim, H., Lee, M., Kim, H., Jeong, J. and Kim., C. 2009. "Characteristics of low-fat meat emulsion systems with pork fat replaced by vegetable oils and rice bran fiber." **Meat Science**. 82: 266-271.

- [16] Sabanis, D.D. and Tzia, C. 2009. "Effect of dietary fibre enrichment on selected properties of gluten-free bread." **LWT- Food Science and Technology**. 42: 1380-1389.
- [17] Abirami, A., Nagarani, G. and Siddhuraju, P. 2014. "Measurement of functional properties and health promoting aspects-glucose retardation index of peel, pulp and peel fiber from *Citrus hystrix* and *Citrus maxima*." **Bioactive Carbohydrate and Dietary Fibre**. 4: 16-26.