Title **The Use of Full-fat Rice Bran as Functional Ingredient in Sausages**

ชื่อเรื่อง **การใช้ประโยชน์เชิงสุขภาพจากรำข้าวในผลิตภัณฑ์ไส้กรอก**

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Abstract

The aim of this study was to formulate sausage that contained fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA) by adding rice bran from sinlek and rice berry varieties. Along the product development process, it was found that 7% (w/w) of rice bran was an appropriate adding level according to the sensory acceptability. Therefore, the mixture of pork back fat, rice bran and commercial rice bran and soybean oil was used as a source of fat in the formulation step. Results from sensory evaluation using 50 panelists showed that overall acceptability scores of the modified sausages containing sinlek rice bran and rice berry bran were not significantly different and were accepted by panelists. Total dietary fiber contents of the modified sausages added sinlek rice bran and rice berry bran were 4 and 5 times higher than that of the control. The modified sausage with rice berry bran contained the highest contents of vitamin E, ß-carotene, lutein, anthocyanins (peonidin, cyanidin), and total polyphenols, as well as antioxidant capacity (FRAP and H-ORAC assays).

Keywords : Rice bran, Sausages, Fatty acids, Phytochemicals, Antioxidant capacity

บทคัดย่อ

รำข้าวจากข้าวพันธุ์สินเหล็กและพันธุ์ไรซ์เบอรี่ถูกนำมาใช้ในการพัฒนาสูตรไส้กรอกเพื่อปรับสัดส่วนของกรดไขมันให้เป็น 1: 1.5: 1 (SFA: MUFA: PUFA) จากประเมินการยอมรับทางประสาทสัมผัสพบว่าไส้กรอกที่เติมรำข้าวร้อยละ 7 ของน้ำหนักส่วนประกอบทั้งหมดได้รับการยอมรับมากที่สุด ดังนั้นในการพัฒนาสูตรไส้กรอกที่มีการปรับสัดส่วนกรดไขมัน จึงใช้ส่วนผสมของมันหมูแข็ง รำข้าว น้ำมันรำข้าวและน้ำมันถั่วเหลืองเป็นแหล่งของไขมันในไส้กรอก ผลการประเมินทางประสาทสัมผัสโดยผู้ทดสอบจำนวน 50 คน พบว่า ไส้กรอกที่มีการปรับสัดส่วนกรดไขมันโดยการเติมรำข้าวทั้งสองชนิด มีคะแนนความชอบโดยรวมที่ไม่แตกต่างกันอย่างมีนัยสำคัญ เมื่อนำไส้กรอกสูตรที่ได้พัฒนาขึ้นมาวิเคราะห์คุณค่าทางโภชนาการเปรียบเทียบกับไส้กรอกสูตรควบคุม พบว่าไส้กรอกที่มีการปรับสัดส่วนกรดไขมันโดยการเติมรำข้าวสินเหล็กและรำข้าวไรซ์เบอรี่มีปริมาณใยอาหารทั้งหมดสูงกว่าไส้กรอกสูตรมาตรฐานประมาณ 4 และ 5 เท่า ตามลำดับ นอกจากนี้ยังพบว่าไส้กรอกที่มีการปรับสัดส่วนกรดไขมันโดยการเติมรำข้าวไรซ์เบอรี่ มีปริมาณวิตามินอี

เบต้าแคโรทีน ลูทีน แอนโธไซยานิน (peonidin และ cyanidin) และโพลีฟีนอล และมีความสามารถในการต้านสารอนุมูลอิสระ (วิเคราะห์โดยวิธี FRAP และ H-ORAC) มากกว่าสูตรควบคุมและสูตรที่เติมรำข้าวสินเหล็ก

คำสำคัญ : รำข้าว ไส้กรอก กรดไขมัน สารพฤษเคมี การต้านสารอนุมูลอิสระ

Introduction

Sausages are widely consumed meat products among Thai people especially teenagers and working people in the cities because of the evolution of life-styles and eating habits. Furthermore, sausages are easy to cook and can make various foods such as adding in bakery products, eating with rice or preparing with main foods (fried rice, fried vegetables, salad) and also eating like a snack between meals.

However, the sausages have low dietary fiber content and contain animal fat which are an essential ingredient representing 20-25% of overall composition. Fat from animal source is considered high in saturated fatty acids which leading to coronary artery disease risk (Krauss et al., 2000; Cengiz and Gokoglu, 2007). The American Heart Assoication recommends the significance of the fatty acid balance at approximately 1: 1.5: 1 for SFA: MUFA: PUFA which generates the best LDL/HDL ratio (Hayes, 2002).

Rice bran is the most important by-product from rice milling process. It has been recognized as a nutritional source due to its high content of lipid, protein, B vitamins and dietary fiber (Huang et al., 2005). Rice bran contains 12-23% oil by weight, a relatively high percentage compared to most other bran sources, and the oil consists of ~20% saturated fatty acids, >40% mono-unsaturated fatty acids and 40% poly-unsaturated fatty acids (Gerhardth and Gallo, 1998; Juliano and Bechtel, 1985).The mono-unsaturated fatty acid can increase or maintain the good cholesterol or high density lipoprotein cholesterol (HDL-C) (Rice Bran Oil and Cholesterol, 2009). Rice bran contains both insoluble and soluble fibers. Soluble fiber in bran binds to cholesterol and bile acids in the gastrointestinal tract to reduce the absorption of cholesterol (Kim et al., 2000). In addition, rice bran contains some antioxidative compounds that have the ability to inhibit the formation or to reduce the concentrations of reactive cell-damaging free radicals. These compounds include carotenoids, vitamin E, γ-oryzanol, and polyphenols (Cheruvanky, 2000; Nam et al., 2006). Moreover recent study showed that bran from pigmented rice also contains anthocyanins and has more antioxidative compounds than bran of nonpigmented rice (Chanphrom, 2007). There were some studies adding rice bran in meat products. Restructured beef roasts containing rice fiber and/or rice bran oil have higher oxidative stability during storage and have lower ratio of saturated fatty acid to unsaturated fatty acid than beef roasts without additives (Kim et al., 2000). Adding small particle size of rice bran less than 10% in emulsified pork meatballs possessed better quality than larger size (Huang et al., 2005).

In recent research, there were the developments of new rice strains which contain high iron content at the range 1.8-2.1 mg/100 g. These rice varities are white rice strain 313 (sinlek rice) and dark purple rice strain 1000 (rice berry). For dark purple rice, it contains up to 25 µg/100 g of ß-carotene and high in vitamin E as 680 µg/100 g which providing high antioxidant capacity in both water soluble as compared to ascorbic acid and lipid soluble as equivalent to Trolox. In bran part also found that it provided the antioxidant capacity greater than 100% purple grape and orange juice (Vanavichit, 2005).

The aim of this research was to improve the nutritional quality of sausage which has the fatty acids ratio of 1: 1.5: 1 (SFA: MUFA: PUFA), beneficial phytochemicals and dietary fiber by using sinlek rice bran and rice berry bran, and determine their physical and chemical properties.

Research Methodology

1. Sample preparation

Sinlek rice bran (non-pigmented rice bran) and rice berry bran (dark purple rice bran) were obtained from the Center of Excellence for Rice Molecular Breeding and Product Development, Kasetsart University, Kamphaengsaen Campus, Nakhon Pathom, Thailand. Before storage, rice bran was heated in a pressure cooker at 110°C for 5 min to inactivate enzyme lipase (Sayre et al., 1982). Samples were vacuum-packed in laminated aluminum foil bags and kept at -20°C for product development.

2. Sausage making

Recipe of the control formula was selected from the study by Chaidet (2007). Lean pork, pork back fat and ice were the main ingredients used. Lean pork and back fat were separately ground through a 3-mm hole plate of an electric meat grinder (KitchenAid Model 5KPM50, St. Joseph, Michigan, USA). The lean pork was cured with 2% sodium chloride, 0.01% sodium nitrite and 0.55% sodium erythorbate at 4°C for 24 h. The cured meat and half of ice were chopped in a bowl cutter (3 blades, locally made) for 4 min, and then the back fat, the remaining ice, spices and other ingredients were added. The mixture was chopped for 6 min (final temperature was approximately 16-17°C). Total chopping time was 10 min. The batter was stuffed into cellulose casing size 20 which obtained from IPS Inst'l CP Interfood (Thailand), Bangkok, Thailand. The stuffed casing was handlinked at 7 cm interval, and the sausages were heated in hot water at 80°C for 20 min. Following cooking, the sausages were cooled immediately by soaking in cold water (ice water) for 10 min, and stored at 4°C overnight before sensory evaluation was performed.

3. Formulation of modified sausage containing fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA)

The optimum size and level of added rice bran were determined before formulating the modified formula. Rice bran was ground using a blender (Moulinex, China) and sieved to separate particle size using. Sinlek rice bran (<60, ≥60 - <80, and ≥80 mesh size) and rice berry bran (≥35 mesh size) were added in the control formula at the level of 5% (w/w). The optimum size of rice bran was selected from sensory evaluation by 5 expert panelists. Then, the optimum level of added rice bran was determined by adding 5, 7 and 9% (w/w) of sinlek rice bran or rice berry bran in the control formula. Sensory test by 5 expert panelists was used as a tool to select the optimum level of rice bran in sausage.

After selecting the optimum level of added rice bran, modified sausage containing fatty acid ratio of 1: 1.5 : 1 (SFA: MUFA: PUFA) was formulated by adding sinlek rice bran or rice berry bran. Pork back fat and commercial rice bran and soybean oil were used to adjust the proportion of fatty acids.

4. Sensory evaluation for acceptability test

A randomized complete block design (RCBD) was conducted for sensory test. Fifty panelists who recruited from staffs and graduate students of the Institute of Nutrition, Mahidol University were asked to evaluate general appearance and overall acceptability by a 7-point hedonic test (7 = like very much, 4 = neither like nor dislike, 1 = dislike very much). Color, flavor, texture and taste of products were evaluated by a 5-point hedonic test (5 = like very much, 3 = neither like nor dislike, 1 = dislike very much). A formula with the overall acceptability score are more than 4 was considered for consumer acceptability.

5. Determination of quality of the modified sausages

The control sausage and the modified sausages adding sinlek rice bran and rice berry bran were prepared on the day of determination the physical properties. For chemical property determination, samples were ground and kept in plastic bottles at -20°C. Three batches of each sausage formula were performed on different days.

5.1 Physical properties

a. Cooking yield

Yield of cooked sausage was measured as a percentage of weight retained after cooking (Thompson et al., 1982). Cooking yield was calculated as:

Cooking yield (%) = (Cooked weight / Raw weight) x 100.

b. Hardness and cohesiveness

Sausage samples were measured hardness and cohesiveness according to texture profile analysis using the TA.XT.plus Texture Analyzer (Stable Micro System Ltd., U.K.). Sausages were cut into cores (1-cm diameter, 2-cm height). Each core was axially compressed at 5 mm/sec to 50% of its original height for 2 cycles at 25±2°C. Hardness is defined as peak force of the first compression, and cohesiveness is defined as the ratio of positive peak area of the second compression to that of the first compression.

c. Color value

Color value was determined by a spectro-colorimeter model JS555 (Color Techno System Corporation, Tokyo, Japan). A tungsten halogen lamp was used as a light source. The value was expressed as L*, a* and b*. The L* value represents lightness, a* and b* values represent redness and yellowness, respectively. Sausage samples were ground before color determination.

5.2 Chemical properties

a. Moisture content

Moisture content was determined by drying sample in a hot-air oven at 100±5°C until constant weigh was obtained according to AOAC method (AOAC, 2005).

b. Fat content

Total fat content was determined by hydrolyzing sample with diluted acid and extracted with petroleum ether using Soxhlet apparatus according to AOAC method (AOAC, 2005). The residue in the extraction flask after solvent removal represents the fat content of the sample.

c. Fatty acid profile

Fatty acids were analyzed according to Jham et al., (1982). They were separated and detected by gas chromatography.

d. Total dietary fiber content

Total dietary fiber (TDF) of sausage sample was analyzed by the enzymatic gravimetric method of AOAC (2005).

e. Vitamin E, ß-carotene and lutein content

Vitamin E, ß-carotene and lutein were saponificated, extracted and analyzed by HPLC according to the method of Speek et al. (1985).

f. Anthocyanin content

Anthocyanidins including cyanidin and peonidin were analyzed by an acid hydrolysis and the high performance liquid chromatography (HPLC) method with some modification according to Zhang et al. (2004).

g. Total polyphenol content

Total polyphenols was determined by the Folin-Ciocalteu method (Brune et al., 1991).

h. Antioxidant capacity

Sausage samples were determined antioxidant capacity by using 2 methods namely the ferric-reducing ability of plasma assay (FRAP) and hydrophilic oxygen radical absorbance capacity (H-ORAC) assay.

– The ferric-reducing ability of plasma assay (FRAP)

FRAP assay was performed according to a modified method of Benzie and Strain (1996). Three milliliters of FRAP reagent was added to one milliliter of each sample. The reaction was monitor for 4 min at 37°C. After 4 min, the UV absorption was recorded at 593 nm using a spectrophotometer (UV-1601 UV-VISIBLE SPECTROPHOTOMETER, SHIMADZU, Japan). Trolox was used as a standard and deionized water was used as blank. The result was expressed as µM of Trolox equivalent (µmole TE) per 100 g of dry weight.

– Hydrophilic oxygen radical absorbance capacity (H-ORAC) assay.

H-ORAC assay was based on method of Huang et al. (2002). The supernatant of sample was diluted with 75 mM potassium phosphate buffer (pH 7.2). Five hundred µl of diluted sample or trolox standard or blank (phosphate buffer pH 7.2) and 3 ml of warmed ($37^{\circ}C$) fluorescein working solution were added into a cuvette with continuously mixing using a magnetic stirrer. Then, 500 µl of 2'-azobis (2-amidinopropane) dihydrochloride (AAPH) solution was added. The intensity of fluorescence was measured at $37^{\circ}C$ at 15 s interval until to 5% intensity, using spectrofluorometer with an excitation wavelength of 493 nm and an emission wavelength of 515 nm. The final ORAC activity was calculated using a linear regression equation between trolox concentration and the net area under curve (AUC) of standard. The net AUC was carried out by subtracting the AUC of the blank from that of the sample. The result was expressed as µM of trolox equivalent (µmol TE) per 100 g of dry weight.

6. Statistical analysis

A randomized complete block design with 3 replications was conducted for the control sample and the modified sausage added sinlek rice bran and rice berry bran. Data were analyzed using SPSS™ software for Windows version 13.0 (SPSS Inc., Illinois, U.S.A.) with the significant difference among groups at 5% level of probability. The results were expressed as mean±standard deviation. Significance among means of physical and chemical properties of all types of sausages were assessed by One-way analysis of variance (ANOVA) followed by Scheffe test. Mann-Whitney U test for two independent groups was applied to test the difference between treatment mean of sensory scores in sausages.

Results

1. Formulation of modified sausage containing fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA)

Results from the sensory evaluation of 5 expert panelists shown that the control sausage contained 5% of ≥80 mesh, sinlek rice bran and ≥35 mesh, rice berry bran were accepted. Therefore, those sizes of rice bran were selected to determine an appropriate amount of rice bran in sausage. The 5, 7 and 9% (w/w) of both rice brans were added in the control formula. The results from sensory test by 5 expert panelists shown that sausages contained 5 and 7% (w/w) of both kinds of rice bran were not different. Therefore, 7% added of sinlek rice bran (≥80 mesh size) and 7% added of rice berry bran (≥35 mesh size) were selected to formulate the modified sausage containing fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA).

The modified sausage formulas were formulated by adding rice bran and adjusted pork back fat and commercial rice bran and soybean oil to reach the fatty acid ratio of 1: 1.5: 1. Weights of pork back fat, rice bran and commercial rice bran and soybean oil were calculated as shown in **Table 1**.

Table 1 Weight ratio of various fat and oil used in the modified sausages

Oil type	g per 100 g oil			Weight	g per oil weight		
	SFA	MUFA	PUFA	(%)	SFA	MUFA	PUFA
Fat from pork back fat	38	50	12	50	19	25	6
Oil from rice bran[1]	25	43	32	6	1.5	2.58	1.92
Rice bran oil[2]	25	43	32	20	5	8.6	6.4
Soybean oil[2]	15	24	61	24	3.6	5.76	14.64
Total				100	29.1	41.94	28.96
FA[3] ratio					1.0	1.4	1.0

[1]Oil from sinlek rice bran or rice berry bran

[2]Commercial cooking oil

[3]FA = Fatty acid

2. Sensory evaluation for acceptability test

Modified sausages containing fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA) were evaluated sensory acceptability test. Scores of sensory acceptability test are presented in **Table 2**. The sensory scores for general appearance and color of modified sausage added sinlek bran were significantly ($P \leq 005$) higher than added rice berry bran, while other sensory scores for overall acceptability, taste, flavor and texture were not significantly different.

Table 2 Sensory acceptability scores of modified sausages added sinlek rice bran and rice berry bran[1, 2]

Sensory characteristic	Type of sausage	
	Added sinlek rice bran	Added rice berry bran
General appearance[3]	$4.66^{a}\pm1.36$	$3.58^{b}\pm1.63$
Color[4]	$3.02^{a}\pm0.98$	$2.44^{b}\pm1.07$
Overall acceptability[3]	4.92±1.19	4.74±1.65
Taste[4]	3.46±0.86	3.58±1.05
Flavor[4]	3.56±0.71	3.68±0.87
Texture[4]	3.42±1.05	3.28±1.03

[1]Results are mean±SD, n=50.

[2]Values with different superscript in the same row indicate significantly different using nonparametric (Mann-Whitney U) test at $P \leq 0.05$.

[3]7-point hedonic scale (7 = like very much, 4 = neither like nor dislike, 1 = dislike very much)

[4]5-point point hedonic scale (5 = like very much, 3 = neither like nor dislike, 1 = dislike very much)

3. Determination of modified sausage containing fatty acid ratio of 1:1:1 (SFA: MUFA: PUFA)

3.1 Physical properties

The modified sausage added sinlek bran and rice berry bran were determined the physical properties compared to the control formula. The results are given in **Table 3**. It was noticed that the cooking yields of the modified sausage added sinlek bran and rice berry bran were not significantly different, but they were significantly higher than the control ($P \leq 0.05$). In term of texture characteristics, hardness and cohesiveness of the control and both modified sausages were not significantly different. When compared the color values of the modified sausages with the control, the modified sausage added sinlek bran had the lowest a* value but it had the highest b* value. The modified sausage added rice berry had the lowest L* and b* values, whereas it had the highest a* value at significant difference $P \leq 0.05$. These results were confirmed by a photograph of sausages as shown in **Figure 1**.

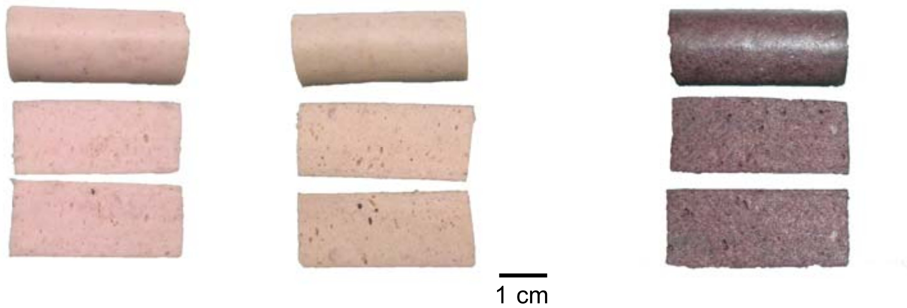
Table 3 Physical properties of the control and the modified sausages added sinlek rice bran and rice berry bran[1, 2]

Physical property	Type of sausage		
	Control	Added sinlek rice bran	Added rice berry bran
Cooking yield	96.61^{b}±0.71	98.92^{a}±0.61	98.87^{a}±0.26
Texture[3]			
Hardness (g)	3698.27±84.36	3636.02±319.20	3778.50±39.26
Cohesiveness (%)	69.68±2.30	62.39±9.46	61.85±1.88
Color value			
L*	68.70^{a}±1.36	63.95^{b}±0.62	28.85^{c}±0.48
a*	$+7.17^{b}$±0.56	$+3.95^{c}$±0.43	$+9.20^{a}$±0.28
b*	$+11.54^{b}$±0.20	$+14.51^{a}$±0.71	$+0.53^{c}$±0.49

[1]Results are mean±SD from 3 replications (3 batches of sausage).

[2]Values with different superscripts in the same row indicate significantly different using Scheffe test at $P \leq 0.05$.

[3]Results are from 15 replicate analyses.



Control added sinlek rice bran added rice berry bran

Figure 1 The modified sausage containing fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA) by adding sinlek rice bran and rice berry bran compared to the control

3.2 Chemical properties

The modified sausages added sinlek rice bran and rice berry bran were determined the chemical properties compared to the control formula. The results in **Table 4** indicated that the control sausage had the greatest moisture content ($P \leq 0.05$), whereas moisture contents of both modified sausages were not significantly different. For fat content, there were not significantly different among three sausage formulas (17.68-18.31 g/100 g). Fatty acid profile of both modified sausages were close to the ratio of fatty acid which calculated in **Table 1** (SFA: MUFA: PUFA; 1.0: 1.4: 1.0). The modified sausages added sinlek rice bran and rice berry bran contained higher total dietary fiber than that of the control (approximately 4 and 5 times, respectively) (**Table 5)**.The recommended daily intake (RDI) for the control and the modified sausages added sinlek rice bran and rice berry bran were 1.40, 5.08 and 6.60%, respectively.

The phytochemicals namely vitamin E, ß-carotene, lutein, anthocyanin (peonidin, cyanidin), and total polyphenol, and antioxidant capacity (FRAP, H-ORAC) of the control and the modified sausages added sinlek rice bran and rice berry bran were shown in **Table 6**. The results revealed that the modified sausage added rice berry bran had the highest content for all analyses at significant difference $P \leq 0.05$. ß-carotene and peonidin in control and the modified sausage added sinlek rice bran were not detected.

Table 4 Chemical properties of the control and the modified sausages added sinlek rice bran and rice berry bran[1, 2]

Chemical property	Type of sausage		
	Control	Added sinlek rice bran	Added rice berry bran
Moisture (g/100 g)	65.43[a]±0.30	61.46[b]±0.10	61.95[b]±0.02
Fat (g/100 g)	18.15±0.53	17.68±0.25	18.31±0.08
Fatty acid profile (%)			
SFA[3]	37.10[a]±0.00	29.80[b]±0.00	29.30[c]±0.14
MUFA[4]	42.00[a]±0.07	39.35[b]±0.07	38.90[c]±0.14
PUFA[5]	20.80[c]±0.00	30.80[b]±0.00	31.65[a]±0.07
SFA: MUFA: PUFA	1.0: 1.1: 0.6	1.0: 1.3: 1.0	1.0: 1.3: 1.1

[1]Results are mean±SD from 3 replications (3 batches of sausage).

[2]Values with different superscripts in the same row indicate significantly different using Scheffe test at $P \leq 0.05$.

[3]SFA = Saturated fatty acid

[4]MUFA = Mono-unsaturated fatty acid

[5]PUFA = Poly-unsaturated fatty acid

Table 5 Total dietary fiber of the control and the modified sausages added sinlek rice bran and rice berry bran[1, 2]

Total dietary fiber	Type of sausage		
	Control	Added sinlek rice bran	Added rice berry bran
Total dietary fiber (g/100 g)	0.69[c]±0.01	2.53[b]±0.06	3.29[a]±0.06
Total dietary fiber (g/serving)	0.35	1.27	1.65
Recommeded daily intake (%RDI)	1.40	5.08	6.60

[1]Results are mean±SD from 3 replications (3 batches of sausage).

[2]Values with different superscripts in the same row indicate significantly different using Scheffe test at $P \leq 0.05$.

Table 6 Phytochemical contents and antioxidant capacity of the control and the modified sausages added sinlek rice bran and rice berry bran per serving (50 g)[1, 2]

Property	Type of sausage		
	Control	Added sinlek rice bran	Added rice berry bran
Vitamin E (µg)	67.85[b]±2.16	53.81[b]±0.13	112.55[a]±7.56
ß-carotene (µg)	ND[3]	ND	3.24±0.05
Lutein (µg)	0.64[b]±0.04	2.61[b]±0.05	43.00[a]±2.82
Anthocyanins (mg)			
Cyanidin	0.24[b]±0.01	0.11[c]±0.01	2.25[a]±0.04
Peonidin	ND	ND	3.09±0.01
Polyphenol (mg eq GA)	48.57[b]±0.36	37.23[c]±1.38	104.05[a]±0.37
Antioxidant capacity (µmole TE)			
FRAP	717.71[b]±40.28	565.63[c]±21.47	932.32[a]±13.19
H-ORAC	692.03[b]±8.57	1053.40[b]±95.04	2180.96[a]±131.76

[1]Results are mean±SD from 3 replications with duplicate analyses.

[2]Values with different superscript in the same row indicate significantly different using Scheffe test at $P \leq 0.05$.

[3]ND = Not detected

Discussion

For formulation and sensory evaluation of the modified sausages containing fatty acid ratio of 1: 1.5: 1 (SFA: MUFA: PUFA), different mesh sizes of both rice brans were selected for adding in the control sausage formula (≥80 mesh size for sinlek rice bran and ≥35 mesh size for rice berry bran). This was due to the different in their physical characteristic where sinlek rice bran was harder than rice berry bran. Therefore sinlek rice bran could be ground to fine particles. For sensory evaluation, the modified sausage added sinlek rice bran had sensory scores for general appearance and color more than those of the sausage with rice berry bran. The results were due to the dark color of rice berry bran. However, the overall acceptability scores of two types of sausage were not significantly different, their scores were more than 4 (cut-off-point). Therefore these two modified sausages still were accepted by consumers.

For physical determination, the cooking yields of two modified sausages were significantly higher than the control ($P \leq 0.05$). The results agreed with the results of Gits (2008) when rice bran was added to a regular-fat hot dog and Luruena-Martínez et al. (2004) who added locust bean/xanthan gum in low-fat frankfurters. The sausage with sinlek bran had the highest b* value according to color of bran (yellow-brown), while the sausage with rice berry bran had the lowest L* and b* values and the highest a* value. These results were attributed to the presence of anthocyanins, responsible for the dark purple color of rice berry bran. For chemical determination, the control sausage had moisture content more than those of the two modified sausages ($P \leq 0.05$). Similar results were reported by Yilmaz (2004) where the moisture contents of samples decreased with more bran addition. In term of total dietary fiber, the modified sausage added rice berry bran had total dietary fiber content significantly higher than the modified sausage added sinlek rice bran and the control. Although the levels of added rice bran in two modified sausages were equal (7% w/w), total dietary fiber content of rice berry bran was higher than that of sinlek rice bran. The results of determination of phytochemical contents, vitamin E, ß-carotene, lutein, anthocyanidin (peonidin, cyanidin), total polyphenol and antioxidant capacity (FRAP, H-ORAC) indicated that the modified sausage added rice berry bran had the highest content for all analyses ($P \leq 0.05$). Hu et al. (2003) reported that red and purple pigmented rice bran contains high amounts of hydrophilic phenolic compounds such as anthocyanins. The concentration of total phenolic compounds in red and purple rice bran is approximately 10 times higher than that in light brown rice bran, indicating that the antioxidant capacity of rice bran is closely related to rice bran color (Goffman and Berman, 2004). Vitamin E, lutein and antioxidant capacity (H-ORAC) of the control and the modified sausage added sinlek rice bran were not significantly different. However, significant lower polyphenol content of the modified sausage added sinlek rice bran was observed compared to that of the control ($P \leq 0.05$). These unexpected results may be due to polyphenol in the modified sausage added sinlek rice bran was used as antioxidant to prevent lipid oxidation of polyunsaturated fatty acids.

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