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Quality of Donut Supplemented with Hom Nin Rice Flour

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Abstract**—**Hom Nin rice (*Oryza Sativa* L.) was processed into flour and used to substitute wheat flour in donuts. The donuts were prepared with 0, 20, 40, 60, and 80% Hom Nin rice flour (HNF). The donuts were subjected to proximate, texture, color and sensory evaluations. The results of the study revealed that the ash, moisture, crude fiber contents increased while crude fat and protein contents decreased as the level of HNF increased. The hardness and chewiness of donut increased as the HNF increased but the cohesiveness, springiness, and specific volume decreased. Color of donut (L*, a*, and b* values) decreased with the addition of HNF. Overall acceptability for the 20-40% HNF additions did not differ significantly from the score of the 100% wheat flour.

Keywords**—**Hom Nin rice, donut, texture evaluation, sensory evaluation.

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I. Introduction

RICE is the major staple food in Thailand. Thailand produced more than 32.6 million tons of rice in 2014-2015 [1]. Rice containing no gluten, low levels of sodium, protein, fat and fiber, and a high amount of easily digested carbohydrates is desirable for certain special diets such as gluten-free food products. Hom Nin rice is a special long-grain strain that has been developed from glutinous black rice from China called Hin Bao. The dark purple to almost black color is due to the presence of anthocyanin and proanthocyanidin pigments which are also antioxidants [2]. Indeed, its antioxidant content is about seven times higher than that of common brown rice [3]. Anthocyanins have been recognized as health-promoting functional food ingredients due to their antioxidant activity, anticancer, hypoglycemic, anti-inflammatory effects, and these functions provide synergic effect with various nutrients *in vivo* [4]. Previous studies show the incorporation of rice flour in the food products. Reference [5] replaced 2% of anthocyanin-rich black rice extract powder of plain bread flour as a nutraceutical source in bread. Reference [2] developed the extruded snack made from Hom Nin rice. The suitable moisture content for HNF was 15% and the optimum conditions for the extrusion process to produce the maximum qualities of Hom Nin rice snacks were a feed rate of 20 g/min, die and transition zone barrel temperature of 120 and 80 °C and screw speed of 250 rpm. Reference [6] developed production of cookies using wheat flour partially substituted with HNF. The optimum partially substituted of 50% HNF had the highest score of overall linking. Reference [7] reported that increasing level of Riceberry flour (10-40% by flour weight) resulted in decreasing stickiness, water absorption, cooking loss, breaking length and sensory attributes of noodle. Therefore, the objective of this research was to use HNF as an ingredient to make the donut of high nutritional quality. The quality of HNF was investigated in terms of physicochemical, textural and sensory of the donut.

II. Materials and Methods

A. HNF Preparation

Hom Nin rice was purchased from a local market in Bangkok, Thailand. The rice was dried using a double drum dryer at 130 °C. Then, it was blended and sieved through an 80-mesh screen. HNF was kept in sealed container at 4 °C until future analysis.

B. Donut Preparation

Wheat donut and the donut with HNF were formulated (Table I). Four additional donut samples were prepared by substituting wheat flour with 20, 40, 60, and 80% HNF. The donut dough was prepared using a hand-mixing the flour, sugar, salt, nonfat dry milk powder and yeast in a mixing bowl. The egg was added and combined with the dry ingredients, followed by the water. Shortening was then added and blended in. The mixture was kneaded to form a dough and transferred to cutting board, and lightly dusted with flour. It was rolled to a thickness of about 1.0 cm and cut into a 4.5 × 4.5 cm square. Donuts were then allowed to proof for 60 min at 35 °C. Proofed donuts were fried in a deep-fryer containing 1.5 L of vegetable oil (rice bran oil) heated to 160 °C. The dough was fried for 80 s on each side for a total of 160 s until it became golden brown on the outside and well cooked on the inside. The fried donuts were then drained on the strainer for 30 min at room temperature [8].

C. Proximate Analysis

The chemical proximate compositions of HNF and donut samples were analyzed according to AOAC methods [9].

D. Donut Color Analysis

The color of the donut samples was measured by a spectrophotometer (Hunter Lab, Color Quest XE, USA) equipped with a D65 illuminant using the CIE L* a* b* system. L* value measures brightness (0-100); a* value represents the red – green coordinates (- is green with + indicating redness) while b* value measures the blue – yellow coordinates (- is blue with + indicating yellowness) of the product. All measurements were performed in triplicate.

TABLE I
RECIPES FOR DONUT PREPARATION

Ingredient	100% Wheat Flour	20% HNF	40% HNF	60% HNF	80% HNF
Wheat flour	100	80	60	40	20
HNF	-	20	40	60	80
Water	49	49	49	49	49
sugar	8	8	8	8	8
Shortening	3.6	3.6	3.6	3.6	3.6
Nonfat dry milk powder	4	4	4	4	4
egg	13	13	13	13	13
yeast	2	2	2	2	2
salt	1	1	1	1	1

E. Specific Volume

The volume of the donut was measured using rapeseed displacement method after 60 min of frying of donuts [10]. Three donuts were put in a metallic container with know volume (V). The container was topped up with rapeseed, the donuts removed and volume of the rapeseed was noted (V_R). Volume (V_L) was then calculated according to:

$$V_L \text{ (ml)} = V - V_R$$

Then, donuts were weighed on a digital scale, W (g). Specific volume (V_s) of donuts was calculated as

$$V_s \text{ (ml/g)} = V_L / W$$

F. Donut Texture Analysis

Texture profile analysis was performed using a Texture Analyzer (Lloyd Instrument, TA plus, UK) with a maximum force of 50 N to imitate the chewing action of the teeth. An adaptor, a cylinder with a diameter of 20 mm, was used. The fried donut samples were measured after 30 min of cooling. The donut samples were compressed at the center to 50% of their original height at a test speed of 1.0 mm/s. The texture parameters, such as hardness, cohesiveness, springiness, and chewiness were measured [11]. Three replicates of donut at each level of HNF were determined.

G. Sensory Evaluation

The fried donut samples were measured after 30 min of cooling. All donut samples were evaluated for color, flavor, taste, softness and overall acceptability of the samples by 30 untrained panelists which consisted of students, employee and visitors of Suan Sunandha Rajabhat University (Bangkok, Thailand) using nine-point hedonic scales, where 9 = extremely like and 1 = extremely dislike. Donut samples were offered in plastic white bowls coded with random 3-digit numbers. Each panelist evaluated six samples in a balanced sequential order. The optimal ratio of HNF in the donut was investigated using sensory qualities in comparison to the control donut. Sensory evaluation was repeated on two different days.

III. RESULTS AND DISCUSSION

A. Proximate Compositions

The chemical composition and color characteristics of HNF are presented in Table II. The moisture, crude fat, crude fiber, protein and ash contents of HNF were 8.43, 1.08, 2.76, 5.53 and 1.45 g/100 g., respectively. The color of HNF had appeared dark red-purple. Lightness (L*), redness (a*), and yellowness (b*) were 43.95, 8.18 and 4.52 respectively.

TABLE II
CHEMICAL COMPOSITION AND COLOR CHARACTERISTICS OF HNF

Parameter	Mean
Moisture content (g/100g)	8.43
Crude fat (g/100 g)	1.08
Crude fiber (g/100 g)	2.76
Protein (g/100 g)	5.53
Ash (g/100 g)	1.45
L*	43.95
a*	8.18
b*	4.52

The proximate compositions; moisture content, ash, protein, crude fat and crude fiber of fried donut with added HNF and control donut are shown in Table III. There were significant differences in the proximate composition. The results showed that the moisture content of all donut samples was in the range of 18.35 – 21.45 g/100 g. The moisture, crude fiber, and ash content increased when the HNF amount in the donut increased. On the other hand, protein content decreased when the HNF amount in the donut increased due to protein content in HNF was lower than wheat flour, which was related to the protein content of HNF (Table II).

TABLE III
CHEMICAL COMPOSITIONS OF DONUT WITH ADDED HNF

Parameter	0% HNF	20% HNF	40% HNF	60% HNF	80% HNF
Moisture content (g/100g)	18.35^{e}	18.65^{d}	19.24^{c}	19.56^{b}	21.45^{a}
Crude fat (g/100 g)	34.84^{a}	33.97^{b}	32.05^{c}	30.46^{d}	28.50^{e}
Crude fiber (g/100 g)	0.11^{a}	0.12^{ab}	0.13^{bc}	0.14^{b}	0.16^{a}
Protein (g/100 g)	6.05^{a}	5.68^{ab}	5.40^{bc}	5.20^{bc}	4.79^{c}
Ash (g/100 g)	1.33^{b}	1.41^{a}	1.41^{a}	1.42^{a}	1.44^{a}

$^{a-e}$ Means followed by a different letter within the same row are significantly different ($P \leq 0.05$)

The crude fat content decreased when the HNF amount in the donut increased. These results are in agreement with [8] who reported that the long-grain rice flour resisted oil absorption more effectively than wheat flour during frying. The crude fat, crude fiber, protein and ash content of all donut samples were in the range of 28.50 – 34.84, 0.11 – 0.16, 4.79 – 6.05 and 1.33 – 1.44 g/100 g., respectively.

B. Color and Specific Volume of Donuts

The color of donut samples was measured based on the values of L*, a*, and b* with each representing the brightness, redness and yellowness, respectively. Color characteristics of donut added with HNF and control donut are shown in Table IV. As compared between the wheat donut and donut added with HNF, the results indicated that as the amount of HNF increased, the appearance of donut added with HNF grew darker. The redness, and yellowness value significantly decreased relative to the HNF content. Specific volume is an importance for the quality of bakery product since it provides the quantitative measurement which strongly correlates to other quality attributes [5]. Significant differences ($P \leq 0.05$) were found in specific volume between donut made from wheat and donut added with HNF (Table IV). Donut made with added HNF had lower specific volume than control. The specific volume was in the range of 1.60 – 19.1 mL/g. These results are in agreement with [5] who reported that increasing the level of anthocyanin-rich black rice extract powder in bread flour, the specific volume was successively decreased which was significantly lower than the control bread.

TABLE IV
COLOR CHARACTERISTICS AND SPECIFIC VOLUME OF DONUT WITH ADDED HNF

Samples	L*	a*	b*	Specific volume (mL/g)
0% HNF	55.9^{a}	15.66^{a}	36.42^{a}	1.91^{a}
20% HNF	38.58^{b}	11.12^{b}	15.69^{b}	1.75^{b}
40% HNF	36.64^{c}	8.69^{c}	8.41^{c}	1.61^{c}
60% HNF	32.06^{d}	5.49^{d}	5.09^{d}	1.61^{c}
80% HNF	32.52^{d}	4.47^{e}	3.05^{e}	1.60^{c}

$^{a-d}$ Means followed by a different letter within the same column are significantly different ($P \leq 0.05$)

TABLE V
TEXTURE CHARACTERISTICS OF DONUT WITH ADDED HNF

Samples	Hardness	Cohesiveness	Springiness	Chewiness
0% HNF	2.66^{c}	0.25^{a}	0.54^{a}	0.23^{e}
20% HNF	3.30^{c}	0.20^{ab}	0.48^{ab}	0.32^{d}
40% HNF	3.62^{c}	0.19^{ab}	0.42^{b}	0.47^{c}
60% HNF	8.07^{b}	0.19^{ab}	0.33^{c}	0.56^{b}
80% HNF	11.38^{a}	0.04^{c}	0.15^{d}	0.63^{a}

$^{a-e}$ Means followed by a different letter within the same column are significantly different ($P \leq 0.05$)

TABLE VI
SENSORY EVALUATION OF DONUT SUPPLEMENTED WITH HNF

Noodles	Color	Flavor	Taste	Softness	Overall acceptability
0% HNF	8.07^{a}	7.41^{a}	7.48^{a}	7.79^{a}	7.69^{a}
20% HNF	6.97^{b}	7.45^{a}	7.00^{a}	7.52^{ab}	7.24^{ab}
40% HNF	6.80^{b}	6.76^{b}	6.88^{a}	7.83^{ab}	7.24^{ab}
60% HNF	6.45^{c}	6.62^{b}	6.59^{b}	5.97^{b}	6.66^{b}
80% HNF	5.69^{c}	6.17^{b}	6.00^{c}	4.83^{c}	5.59^{c}

$^{a-c}$ Means followed by a different letter within the same column are significantly different ($P \leq 0.05$)

C. Texture of Donuts

Donut texture was determined as hardness, cohesiveness, springiness index and chewiness using a Texture Analyzer. As shown in Table V, it is evident that all texture parameters of the experimental donuts were significantly different. The hardness is defined as the peak force of the first compression of the product [12]. The results indicated that as the amount of HNF increased, the hardness and chewiness of donut increased. The hardness of control donut was not significantly different with 10-40% HNF. The trends of chewiness in fried donut follow replacement with HNF. It might be due to poor gas retention ability of weak gluten networks [5]. The cohesiveness indicates how well the product withstands a second deformation relative to how it behaves under the first deformation and springiness is used to indicate how well a food product physically springs back after it has been deformed during the first compression [12]. The cohesiveness and springiness were significantly different with the variation of HNF content increased. The results indicated that cohesiveness and springiness decreased as the amount of HNF increased. The springiness of control donut was not significantly different with the addition of 0-20% HNF. The cohesiveness of control donut was not significantly different with the addition of 0-60% HNF.

D. Sensory Evaluation

The sensory of donuts with HNF addition was done to choose the most appropriate HNF that is 20, 40, 60 and 80% for the formulation of the donuts. The results presented in Table VI. The donuts were evaluated for their sensory quality characteristics color, flavor, taste, texture and overall acceptability. All attributes of control donut were significantly different with 0-80% HNF. The results indicated that color score decreased with the addition of 20-80% HNF donuts and flavor score decreased by the addition of 20-40% HNF donuts were not the significant difference. The quantity of HNF increased, the color of donuts darken which had an effect on color score decreased. The taste score of donuts decreased, but was not significantly different with 0-40% HNF. The softness score of control donut was not significantly different with 0-40% HNF and decreased significantly by the addition of 60-80% HNF which was related to hardness and springiness index of donut with added HNF (Table V). The overall acceptability score of control donut was not significantly different with 20-40% HNF and decreased significantly by the addition of 60-80% HNF. This finding might conclude that using the HNF as a proportional substitution for wheat flour up to 40% could obtain the similar quality and pleasant appearance as control donut.

IV. CONCLUSION

Higher levels of substitution of wheat flour with HNF resulted in lower crude fat and protein content and increase in moisture content of donut. There were significant differences in color characteristics. The brightness, redness and yellowness value significantly decreased when the levels of higher HNF. Increasing the level of HNF increased hardness and chewiness and decreased cohesiveness, springiness and specific volume with HNF. Acceptable donut could be made by substitute with up to 40% HNF.

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