
Development of low-energy snack bars made from native Thai black rice mixed with durian sauce

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Kangkawisut, N., Phuangborisut, S., Khunphutthiraphi, T., Lertnimitmongkol, W., Tubklang, R. and Mongkontanawat, N. (2026). Development of low-energy snack bars made from native Thai black rice mixed with durian sauce. *International Journal of Agricultural Technology* 22(2):683-698.

Abstract The result indicated that durian sauce with composed of durian pulp : sugar : honey (75 : 15 : 10) showed high preference scores in terms of color, aroma, taste and overall liking, with average scores of 7.10 ± 0.99 , 7.00 ± 0.66 , 7.20 ± 1.03 and 7.20 ± 1.03 ; respectively. Next, 10% concentration of this durian sauce was the optimum condition in term of the preference scores of aroma, taste, texture, and overall liking from sensory assessments. The chemical composition of develop snack bar, moisture, protein, fat, ash and carbohydrate content were 8.96%, 5.69%, 10.19%, 1.06% and 74.10% w/w, respectively. Second, some properties of developed snack bars was performed compare with the commercial snack bar. Results showed that the developed snack bar mixed with durian sauce and dried fruits exhibited significantly ($p < 0.05$) lower the value of lightness(L*), redness(a*), yellowness(b*), water activity and caloric content with the data 35.83 ± 0.05 , 6.33 ± 0.02 , 1.80 ± 0.02 , 0.36 ± 0.00 and 160.00 ± 0.00 Kcal, respectively. However, the hardness of the developed snack bar was significantly ($p < 0.05$) higher than the commercial snack bar with the value 35.90 ± 0.06 N. Finally, the final 100 consumers acceptance testing was determined, those consumers were moderately satisfied with the product showing the average score of 6.91 ± 0.83 . In conclusion, the developed snack bar interest to provided the health benefit and prolong shelf life storage due to its low-caloric and water activity levels than those the commercial one.

Keywords: Low-energy snack bar, Native black rice, Durian sauce

Introduction

Nowadays, consumers are increasingly interested in healthy food. Snack bars are increasingly popular as convenient, nutritious food options that cater to busy lifestyles. They serve as an important vehicle for delivering bioactive components, fiber, and other nutrients in a compact form.

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Native grains are interesting for their potential to improve the nutritional profile of snack products due to their higher content of antioxidants, vitamins, minerals, and dietary fiber compared to highly processed cereal grains (Chen *et al.*, 2022). Native Thai black rice (*Oryza sativa* L.), local name is Mae Phaya Thong Dam. Its pigmented with anthocyanins has been shown to exhibit strong antioxidant activity, potential health benefits such as reducing oxidative stress, and supporting anti-inflammatory effects (Liu *et al.*, 2019; Patel and Kumar, 2021). In addition, Native black rice (Mae Phaya Thong Dam) rice from Chanthaburi Province has long been grown as upland rice for family consumption. It has long been a medicinal plant in Ban Chong, an indigenous group in Khao Khitchakut District. It is known as black rice. In 2008, it was registered under the Plant Varieties Act of 1975 and certified by the Department of Agriculture. Black rice benefits include its anthocyanin content, which can help reduce tissue inflammation, reduce clogged arteries, prevent obesity, hypertension, gout, and diabetes. It also helps nourish the eyes, is an antioxidant, and can inhibit the growth of epidermal growth factor receptor in cancer cells. A study by (Sangkitikomol *et al.*, 2008) found that black sticky rice has the highest amount of anthocyanin, which has the highest antioxidant properties, significantly compared to red rice and black rice.

Meanwhile, durian (*Durio* spp.), known colloquially as “the king of fruits,” is rich in energy, vitamins (C and B), minerals, and distinctive flavor compounds (Tan, 2018). Furthermore, it is also a source of carbohydrates, protein, and fat. Moreover, durian has a high glycemic index (GI), a high-fat food. Therefore, it is recommended to consume durian in moderation. Durian is not suitable for diabetics as it causes a rapid rise in blood sugar and can also cause heat and discomfort. However, various parts of the durian can be used medicinally. The leaves have a bitter, astringent taste and are effective in reducing fever, curing jaundice, expelling parasites, and drying up pus. Durian flesh has a sweet, warm taste and has heating properties. It can treat skin diseases, dry up abscesses, and expel parasites. Durian rind has an astringent and bitter taste and is used to heal wounds, treat lymphatic problems, blisters, and abscesses. The roots have a bitter, astringent taste and are used to treat fever and diarrhea (Somsri, 2017). Although durian is nutrient-dense, its high sugar and lipid content can pose challenges when used in snack formulations meant to be “low-energy” or moderate in caloric density (Tan, 2018; Nguyen *et al.*, 2023).

Therefore, the combination of native black rice, durian and local dried fruit into a snack bar formulation offers an opportunity to harness their complementary properties: black rice’s fibre and antioxidant capacity, and durian’s natural flavor, potential micronutrients, and consumer appeal.

In term of the beneficial of snack bar, rice, there are many previously research as below. For example, Lertnimitmongkol and Mongkontanawat (2020), determined to develop of “Khao Hawm Mae Paya Tong Dam Black Rice” (*Oryza sativa* L.) bar mixed with fried Pisang Mas (*Musa sapientum*). They founded that the most satisfaction ratio of Khao Hawm Mae Paya Tong Dam Black Rice and Fried Pisang Mas was 37:19 at the statistical significance of $p < 0.05$. For the physical properties, brightness (L^*), red color (a^*), blue color (b^*) and hardness value were, 24.17, 0.84, 5.08 and 28.43 N, respectively. For the chemical properties, water activity (a_w), moisture content, fat, protein, fiber, ash and carbohydrate were 0.25, 7.57 %, 11.48 %, 2.14 %, 19.42 %, 1.17 % and 58.22 % w/w, respectively. In addition, total plate count was less than 1×10^3 and yeasts and molds count was 10 CFU/g.

Siswanti *et al.* (2020) studied the formulation of snack bars made from black rice bran (*Oryza sativa* L.) and sweet potato flour (*Ipomoea batatas* L.). The best formulation of snack bars based on physical, chemical and sensory characteristics was F3 (30% black rice bran:70% sweet potato flour). It was composed of 6g of black rice bran, 14g of sweet potato flour, 10g of whole milk, 12g of powdered sugar, 0.25g of vanilla, 8g of egg white, 4g of liquid margarine, and 8g of water. Furthermore, it has moisture, ash, protein, fat, carbohydrates, dietary fiber, total calories, vitamins B1, and antioxidant activity of IC50 contents, such as 20.9%, 3.1%, 7.5%, 12.6%, 76.8%, 12.5%, 84.9 Kcal/25 g; < 0.25 ppm and 443 mg/mL, respectively.

Pramitasari *et al.* (2021) investigated sensory evaluation, antimicrobial activity of snack bar from black soybean and black rice. They found that formula 2 (50% of black soybean and 50% of black rice) showed the best snack bar based on sensory evaluation and pathogenic bacteria inhibition assay. In the same year, Kunna *et al.* (2021) determined to develop of high fiber cereal bar product from Sinlek brown rice.

Panritdam *et al.* (2022) performed the ratio of Thai - colored indica rice (*Oryza sativa* cv. Riceberry) and dried date plum (*Diospyros lotus* L.) fruits for the development of a crispy riceberry snack bar. All four major using the ratio of riceberry rice and dried date plum fruits were 100 : 0, 50 : 50, 60 : 40 and 40 : 60 respectively, based on a sensory evaluation assessment. The results showed that the optimum ratio of riceberry rice and dried date plum fruits was 60:40 and had the highest overall acceptability ($p \leq 0.05$) when compared to control. The hardness of the developed snack bar from riceberry rice mixed with dried date plum fruits was 119.96 g. A color value of L^* increased a^* and b^* decreased as the addition level of dried date plum fruits increased. The water activity (a_w) of the product was 0.38. The content of moisture, carbohydrate, protein, fat, fiber

and ash was 3.93, 37.35, 14.30, 25.13, 11.22 and 20.15% and would yield energy of 432.87 Kcal per 100 g, respectively.

Lainumngen *et al.* (2022) also investigated the development Thai colored indica rice (*Oryza sativa* cv. Riceberry), black sticky rice (*Oryza sativa* cv. Leum Phua), white glutinous rice (*Oryza sativa* cv. RD6). The results showed that the lowest free water was observed in both Riceberry and soaked RD6 formulations with water activity below 0.42. Leum Phua and Riceberry recipes had the lowest brightness. The crispy rice bar from Leum Phua sticky rice had the highest total anthocyanin content, followed by Riceberry rice. According to sensory evaluation, the color score was high in the RD6 and soaked RD6 formulations. During the storage for 2 months, the increase of water activity and lipid peroxidation were observed. However, there was no growth of pathogenic microorganisms. The crispy rice by soaked RD6 formula was acceptable up to 2 months of storage.

However, there is no research on development of low-energy snack bars made from native Thai black rice mixed with durian sauce and dried fruits has been found. Therefore, the aims of this research were to determine the durian sauce formulation development and then the best formula was chosen to investigate the development of snack bars from native Thai black rice mixed with durian sauce and dried fruits (rambutan, mangosteen, and cranberry). Lastly, its some properties were compared with the commercial snack bar.

Materials and methods

Material preparation

The preparation of Mae Phaya Thong Dam fragrant rice, It was cooked in the at a rice-to-water ratio of 1:1. Following cooking, the rice was thinly spread onto trays and dried in a hort air oven at 60 °C for 10 hours. The dried rice was then deep-fried at 120 - 130°C. or until the rice puffs up. Subsequently, the fried rice was re-dried in a hot air oven at 60°C for 10 – 15 minute to remove residual oil. Then, pack the rice in vacuum-sealed bags and seal them tightly to preserve the rice. For other ingredients, honey (Doikam), sugar (Rin) and dried cranberries were purchased from the local market. Durian (Mongtong cultivar), ramtutan and mangosteen were brought from the local farmer. Dried rambutan and mangosteen were prepared. Rambutan and mangosteen obtained from local farmers were peeled and thinly spread onto trays. They were then dried in a hot air oven at 65°C for 12–18 hours or until completely dry. The dried fruits were packed in vacuum-sealed bags seal them tightly to preserve the rice before using it.

Development of durian sauce formulation

Downgraded durian pulp (soft and unsuitable for fresh consumption) were prepared. Then, a formulation durian sauce was optimized using a mixture design experimental approach, with the following ingredient proportions: durian pulp: 65 - 85%, granulated sugar: 5 - 15%, honey: 10 - 20%. So, five treatments for ratio of durian pulp: sugar and honey were produced such as 65:15:20, 75:5:20, 75:15:10, 75:10:15 and 85:5:10 (Table 1).

The durian sauce formulations derived from the mixture design were prepared by heating all ingredients to 65°C for 5 minutes. The mixture was then blended using a multi-purpose blender. It was then filtered through a 0.5 mm sieve and allowed to cool. Then, It was packed in a sealed container. Samples were analyzed for color parameters using the Hunter Lab Color system, water activity (a_w) using a water activity meter, and pH value using a pH meter. Sensory evaluation by 9-point hedonic scales was conducted with 30 trained panelists, who assessed the products based on color, aroma, taste, texture and overall liking using a 9-point hedonic scale (1 = Dislike extremely, 9 = Like extremely).

Table 1. Durian sauce formulation based on mixture design

Treatments	Ratio (%w/w)		
	Durian pulp	Sugar	Honey
1	65	15	20
2	75	5	20
3	75	15	10
4	75	10	15
5	85	5	10

Development of the native black rice snack bar mixed with durian sauce

Based on significantly ($p < 0.05$) highest from sensory evaluation, the best durian sauce was selected to study in this section. Based on the previously observation, the combination of puffed rice, dried fruits (rambutan, mangosteen, and cranberry) were mixed as the ratio of 60:15:5:20. Then, four treatments of various concentrations of durian sauce such as 5, 10, 15 and 20%w/w were mixed together. Then, all the ingredients were molded in the molds according to the size (4x12cm). Next, the samples were baked in the oven at 150 °C for 15 minutes. Then, its were pack into bags and seal the bags tightly and then sensory evaluation. The snack bar's sensory investigation was evaluated by 50 panelists, assessing color, smell, taste, texture, and overall liking using the 9-point hedonic scale (1 = Dislike extremely, 9 = Like extremely) as mention previously.

Some properties determination of developed snack bar mixed with durian sauce

Based on significantly ($p < 0.05$) highest from sensory evaluation, the best treatment was chosen to investigate in this part. The developed prototype bar was determined chemical composition such as moisture content, protein, fat, ash, carbohydrate content (AOAC, 2016). Furthermore, the developed prototype snack bar were final sensory evaluation by central location test with 100 consumers. In addition, some properties were compared with the commercial bar including color parameters (L^* , a^* , b^*), moisture content, water activity (a_w) as previously mention. Also, texture analysis was performed using a texture analyzer (model: LLOYD Instruments, TA plus, UK). Caloric determination was determined through a bomb calorimeter (model: Parr, 610).

Statistical analysis

The data were collected and analysed by analysis of variance (ANOVA) with significance at $p < 0.05$. Significant differences among mean values were determined by Duncan's multiple range test. All statistical analyses were performed using computer software. (Helge, 2009).

Results

Development of durian sauce formula

According to five treatments of the combination of ingredients of durian pulp : sugar : honey were produced and determined sensory evaluation and some properties investigation. The result was found that the high preference scores in terms of color, aroma, taste and overall liking for durian pulp : sugar : honey (75 : 15 : 10), with average scores of 7.10 ± 0.99 , 7.00 ± 0.66 , 7.20 ± 1.03 and 7.20 ± 1.03 respectively (Figure 1).

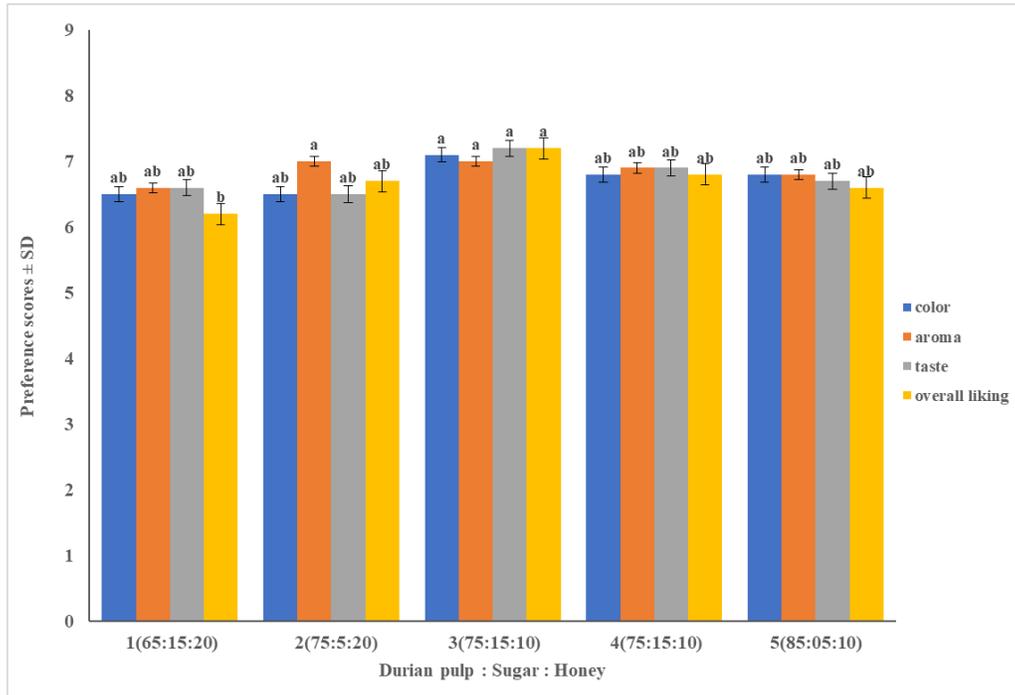


Figure 1. Sensory evaluation of durian sauce formulation with various concentrations of durian pulp, sugar and honey

For color parameter, brightness (L^*), green color (a^*), yellow color (b^*), Significantly ($\rho < 0.05$) highest lightness (L^*) was found in treatment 5 (ratio of durian pulp : sugar : honey; 85 : 5 : 10), whereas, lowest was exhibited in treatment 4 (ratio of durian pulp:sugar:honey; 75:10:15) which the value 46.31 ± 0.20 and 43.18 ± 0.03 ; respectively.

Significantly ($\rho < 0.05$) highest greenness (a^*) was found in treatment 1 (ratio of durian pulp : sugar : honey; 65 : 15 : 20), while, lowest was exhibited in treatment 4 (ratio of durian pulp : sugar : honey; 75 : 10 : 15) which the value -0.80 ± 0.03 and -1.70 ± 0.02 ; respectively.

Significantly ($\rho < 0.05$) highest yellowness (b^*) was found in treatment 3 (ratio of durian pulp : sugar : honey; 75 : 15 : 10), whereas, lowest was exhibited in treatment 1 (ratio of durian pulp : sugar : honey; 65 : 15 : 20) which the value 11.60 ± 0.00 and 8.05 ± 0.01 ; respectively (Table 2). Overall, the obtained snack bar was purple color.

Table 2. Color parameters, brightness (L*), green color (a*), yellow color (b*) of durian sauce formulation with various concentrations of durian pulp, sugar and honey

Durian pulp : Sugar : Honey	Color parameters		
	L*	a*	b*
1(65:15:20)	45.27±0.21 ^b	-0.80±0.03 ^a	8.05±0.01 ^c
2(75:5:20)	44.24±0.07 ^c	-1.25±0.05 ^c	10.20±0.02 ^c
3(75:15:10)	43.93±0.03 ^c	-1.33±0.01 ^c	11.60±0.00 ^a
4(75:10:15)	43.18±0.03 ^d	-1.70±0.02 ^d	8.71±0.03 ^d
5(85:5:10)	46.31±0.20 ^a	-1.07±0.02 ^b	11.28±0.04 ^b

Significantly ($\rho < 0.5$) highest of a_w was treatment 1 (the combination of durian pulp : sugar : honey; 65 : 15 : 20), wherese significantly lowest was exhibited in treatment 3 (the combination of durian pulp : sugar : honey; 75 : 15 : 10) (Figure 2).

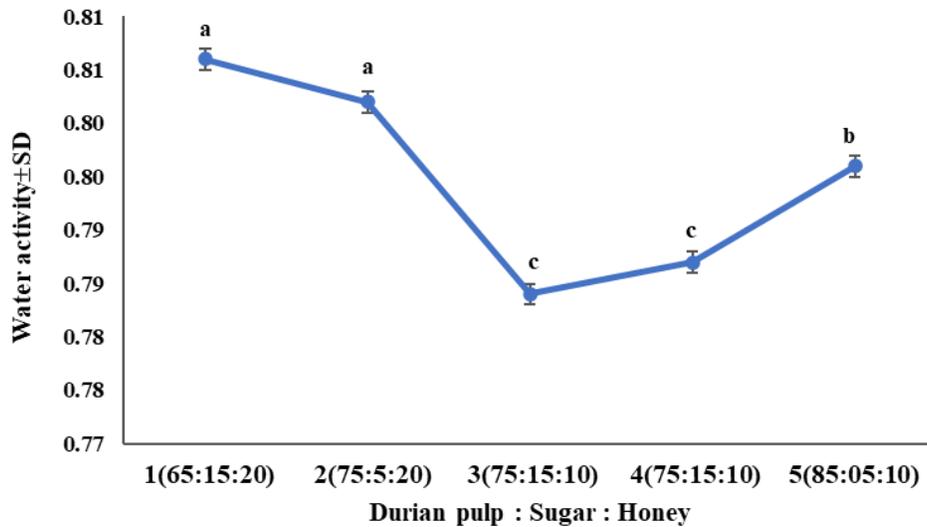


Figure 2. Water activity (a_w) of durian sauce formulation with various concentrations of durian pulp, sugar and honey

For pH content, the values were corresponding with the concentration of durian pulp. Significantly highest was showed in treatment 5 (85 : 5 : 10), while, significantly lowest was demonstrated in treatment 1 (65 : 15 : 20) (Figure 3).

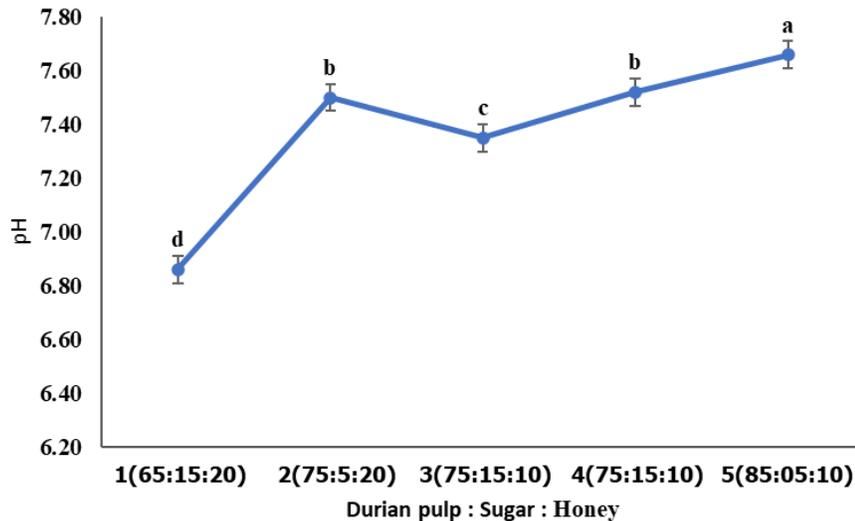


Figure 3. pH of durian sauce formulation with various concentrations of durian pulp, sugar and honey

Development of the native black rice snack bar mixed with durian sauce

Four treatments of the various concentration of durian sauce were mixed in the combination of four ingredients including puffed rice and dried fruits (rambutan, mangosteen, and cranberry) as mention above. Our result found that 10% concentration of durian sauce had the highest sensory evaluation. The preference scores in terms of aroma, taste, texture, and overall liking were exhibited for 7.13 ± 0.56 , 6.93 ± 0.60 , 7.20 ± 0.54 , and 7.07 ± 0.58 , respectively. In contrast, the color preference score did not significantly difference from others treatment (Figure 4). Then, the developed snack bars was analyzed chemical composition. The result indicate that the moisture content, protein, fat, ash and carbohydrate were 8.96%, 5.69%, 10.19%, 1.06% and 74.10% w/w, respectively (Figure 5). Next, the developed snack bar (Figure 6) was tested sensory evaluation by 100 consumer acceptance, it was fond that the consumers were moderately satisfied with the product showing the average score of 6.91 ± 0.83 .

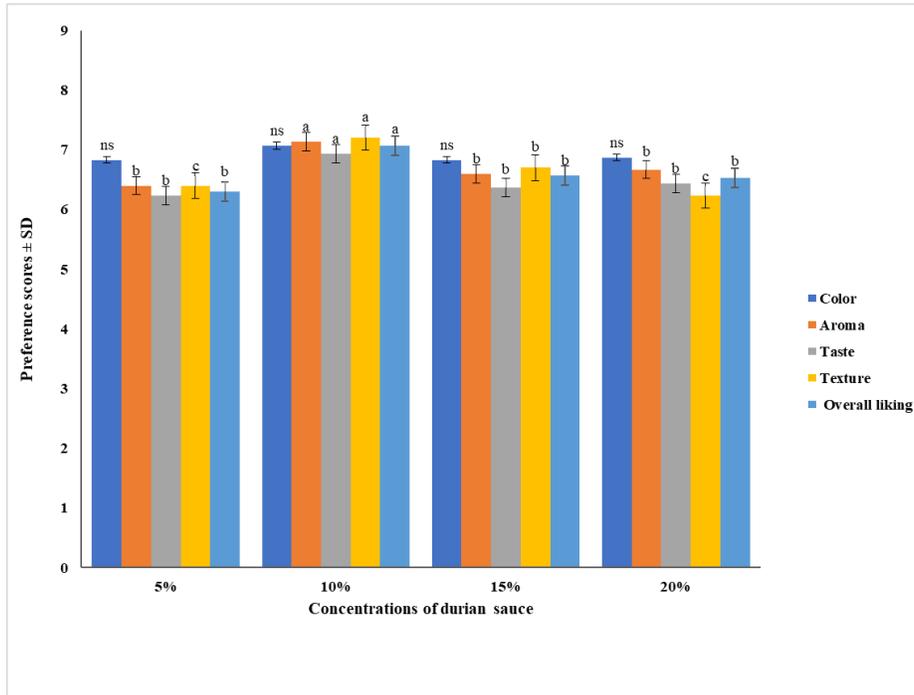


Figure 4. Sensory evaluation of the native black rice snack bar mixed with durian sauce and dried fruits

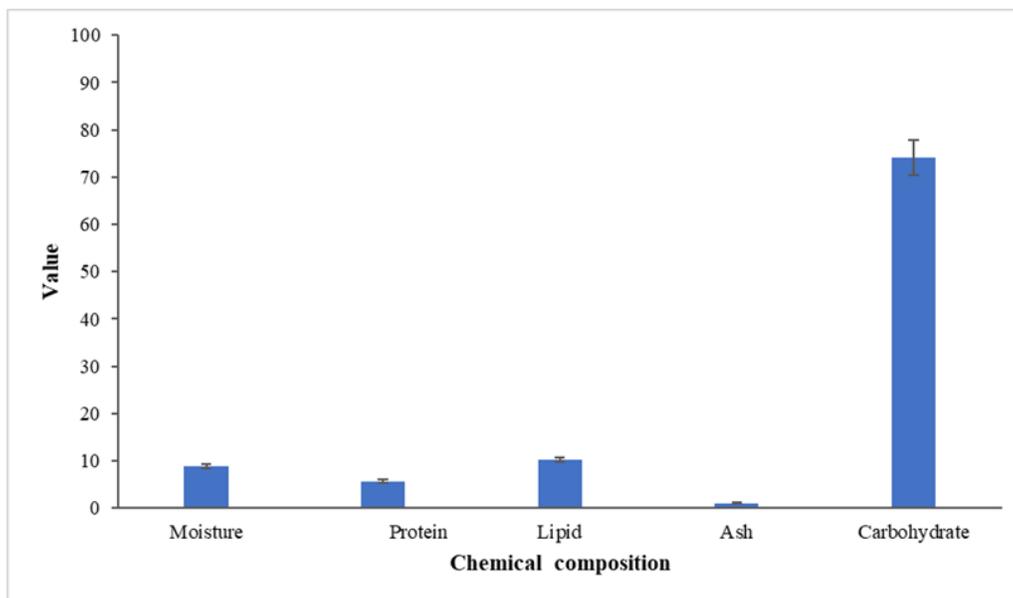


Figure 5. Chemical composition of the developed native black rice snack bar mixed with durian sauce and dried fruits



Figure 6. The developed native black rice snack bar mixed with durian sauce and dried fruits.

Lastly, the developed snack bar mixed with durian sauce and dried fruits was observed some properties including color parameters (L^* , a^* , b^*), water activity, hardness and energy content compared with those commercial snack bar. Our result indicated that the developed snack bar mixed with durian sauce exhibited significantly ($p < 0.05$) lower the value of lightness (L^*), redness (a^*), yellowness (b^*), water activity and caloric content with the data 35.83 ± 0.05 , 6.33 ± 0.02 , 1.80 ± 0.02 , 0.36 ± 0.00 and 160.00 ± 0.00 Kcal, respectively. However, the hardness of the developed snack bar was significantly ($p < 0.05$) higher than the commercial snack bar with the value 35.90 ± 0.06 N (Table 3). In addition, from the microbiological properties investigation, total plate count was less than 1×10^3 and yeast and molds count was 10 CFU/g.

Table 3. Quality of the native black rice snack bar mixed with durian sauce compared with the commercial snack bar

Properties	Commercial snack bar	Snack bar mixed with durian sauce and dried fruits
L^*	42.44 ± 0.19^a	35.83 ± 0.05^b
a^*	9.47 ± 0.12^a	6.33 ± 0.02^b
b^*	3.78 ± 0.06^a	1.80 ± 0.02^b
Water activity	0.47 ± 0.00^a	0.36 ± 0.00^b
Hardness (N)	33.94 ± 0.00^b	35.90 ± 0.06^a
Energy content (Kcal)	173.00 ± 0.00^a	160.00 ± 0.00^b

^{a-b} Mean values with different letters in each column are significantly different ($p < 0.05$)

Discussion

According to durian sauce formulation development, highest preference scores in terms of color, aroma, taste and overall liking for the combination of durian pulp : sugar : honey (75 : 15 : 10) were found. Significantly ($p < 0.5$) highest a_w was treatment 1 (the combination of durian pulp : sugar : honey; 65 : 15 : 20), while, significantly lowest was exhibited in treatment 3 (the combination of durian pulp : sugar : honey; 75 : 15 : 10). This could be the effect of the concentration of honey. High concentrations of honey tend to be increase the a_w value because of honey is hygroscopic and it absorbs moisture from the surrounding environment, therefore, honey can draw in free water, increasing the overall mobility of water in the product and raises the a_w value (Cavia *et al.*, 2006).

For pH content, the values were depended on the concentration of durian pulp. Significantly highest was showed in treatment 5 (85 : 5 : 10), whereas, significantly lowest was demonstrated in treatment 1 (65 : 15 : 20) (Figure 4). Because durian pulp have less acidity (approximately 7). So, the pH was increased significantly depending on the concentration of durian (Arsa *et al.*, 2021).

Then, the significantly consumers acceptance durian sauce (treatment 3; durian pulp : sugar : honey; 75 : 15 : 10) was chosen to assessed development of native black rice snack bar mixed with durian sauce and dried fruits. Four treatments were performed. Our result indicated that significantly ($p < 0.05$) highest sensory evaluation showed in treatment 2 (10 % durian sauce). This could be this concentration is the optimum concentration that not have deep smell of durian.

Finally, the developed native black rice snack bar mixed with durian sauce and dried fruits was determined some properties compare with the commercial snack bar. The result indicated that our developed product exhibited significantly ($p < 0.05$) lower the value of lightness (L^*), greenness (a^*), yellowness (b^*), water activity and caloric content. On the other hand, the hardness of the developed snack bar was significantly ($p < 0.05$) higher than the commercial snack bar. Interestingly, our developed snack bar had low-energy and low water activity than the commercial snack bar. Since, water activity in food is an important factor in controlling and preventing food product spoilage, which has a direct effect on the shelf life of the product. Because the water activity in food is a factor indicating the level of water activity that microorganisms use for growth and affects the growth of microorganisms which is the cause of food spoilage (Iamkampang and Inget, 2015). Microorganisms can grow when water activity in food is 0.6 or higher (Chittapalo

et al., 2013). So, our product was considered a low free water activity (a_w), it could be help to extend the shelf life storage.

Moreover, from the calorie content value, that each piece contained a low energy value of 160 kilocalories. per 37 grams. This developed snack bar typically contain no more than 200 calories per piece and typically range between 30–60 grams per piece. This is considered an appropriate level for daily consumption without providing the body with excessive energy. Therefore, it can be a healthy snack option, suitable for both those who want to control their weight and those who need energy for work or exercise. In addition, The Ministry of Public Health Notification (No. 182) B.E. 2541 on Nutrition Labels has specified the amount of food per serving of Granola Bars and Rice Cereal Bars at 40 grams. (Ministry of Public Health, 1998).

From the chemical composition investigation, the developed snack bar products made from native black rice mixed with durian sauce has been found to have nutritional components suitable for health-conscious consumers, particularly those seeking weight control or seeking nutritious, low-energy snack bar alternative energy sources. The moisture content of 8.96% is considered appropriate for a dried food product, as low moisture content extends shelf life and reduces the risk of spoilage-causing microorganisms (AOAC, 2016; U.S. Food and Drug Administration, 2020). The protein content of 5.69% indicates that this product can still be a suitable protein source, especially when using Mae Phaya Thong black rice, a local rice variety with high protein and dietary fiber levels (National Rice Research Center, 2019). The fat content of 10.19% may seem relatively high for a low-calorie snack. However, considering the fat source, which may come from durian, which contains good unsaturated fatty acids, and the addition of grains or nuts to enhance the flavor, it is considered acceptable according to nutritional guidelines for health (Charoenkiatkul *et al.*, 2016). The ash content of 1.06% indicates the mineral content of the product. which is good for the body when consumed in appropriate amounts. The carbohydrate content is 74.10%, which comes from rice and fruits in the formula.

The microbiological properties of developed snack bar, the total plate count of microorganisms and the yeasts and molds count not exceed the standard criteria for community products, vegetables, fruits, and compressed grains (M.P.C. 902/2019), the total plate count of microorganisms must be less than 1×10^6 colonies per 1 gram of sample, and the yeasts and molds not exceed 100 colonies per 1 gram (Thai Industrial Standards Institute, 2019). In addition, this is because microorganisms will grow with difficulty under a water activity in the medium that is equal to 0.7 or lower (Rattanapanon, 2014).

In conclusion, from durian sauce formulation development, treatment 3 with the combination of durian pulp, sugar and honey (75 : 15 : 10) was chosen

in term of high preference score from sensory assessment. Then, this formulation was mixed in development of native black rice snack bar section. Also, from sensory evaluation, treatment 2 (10 % of durian sauce) was exhibited high preference score in term of aroma, taste, texture and overall liking. Interestingly, the developed native black rice snack bar indicated low caloric content and water activity. Therefore, our product could be a low-energy snack bar and prolong shelf life. Moreover, this product development could be add value to local rice to become a healthy low energy product, stored for a long time and convenient for transportation. However, some properties could be further investigation including shelf life, anthocyanin content, bioactive compounds and antioxidant properties.

Acknowledgments

This research was supported by the Science, Research and Innovation Promotion Fund, Thailand Science Research and Innovation (TSRI), through Rajamangala University of Technology Tawan-Ok (Grant No.: FRB 4694634). We would also like to express our gratitude to the Department of Food Innovation and Business, Faculty of Agricultural Industrial Technology, for providing the facilities used in this research. Special thanks go to all research collaborators, faculty members, and support staff involved, whose contributions made the successful completion of this study possible.

Conflicts of interest

The authors declare no conflict of interest.

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(Received: 7 October 2025, Revised: 2 January 2026, Accepted: 14 January 2026)