

การพัฒนาผลิตภัณฑ์วaffleฟิลกรอบผสมปูทะเล Product Development of Crispy Mud Crab Waffles

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาผลิตภัณฑ์วaffleฟิลกรอบผสมปูทะเล โดยศึกษาตำรับพื้นฐานของวaffleฟิลกรอบและประเมินคุณภาพทางประสาทสัมผัส ได้แก่ ลักษณะที่ปรากฏ สี กลิ่น รสชาติ เนื้อสัมผัส และความชอบโดยรวม โดยใช้ผู้ทดสอบจำนวน 50 คน ด้วยวิธีการให้คะแนนความชอบแบบ 7 ระดับ (7-Point Hedonic Scale) ผลการศึกษาพบว่าตำรับที่ 1 ได้รับการยอมรับสูงสุด โดยมีค่าเฉลี่ยด้านสี กลิ่น รสชาติ เนื้อสัมผัส ลักษณะที่ปรากฏ และความชอบโดยรวมเท่ากับ 5.60 ± 0.99 5.70 ± 0.98 5.35 ± 0.98 5.70 ± 1.16 5.90 ± 1.10 และ 5.78 ± 0.97 ตามลำดับ จากนั้นศึกษาผลของการเติมเนื้อปูทะเลในระดับร้อยละ 5 10 และ 15 (โดยน้ำหนักแห้ง) พบว่าการเติมเนื้อปูทะเลร้อยละ 5 ให้ค่าการยอมรับสูงสุด โดยมีค่าเฉลี่ยเท่ากับ 6.33 ± 0.60 6.00 ± 0.98 6.03 ± 0.92 5.94 ± 0.91 5.78 ± 0.88 และ 6.03 ± 0.85 ตามลำดับ ผลิตภัณฑ์ที่ได้รับการยอมรับสูงสุดถูกนำไปวิเคราะห์คุณสมบัติทางกายภาพและเคมี พบว่ามีค่า water activity (a_w) เท่ากับ 0.50 ± 0.01 ค่าสี L^* 51.44 ± 0.23 a^* 6.30 ± 0.12 และ b^* 43.32 ± 0.17 และค่าความกรอบ 5.77 ± 0.24 นิวตัน ในขณะที่องค์ประกอบทางเคมีประกอบด้วยโปรตีน 12.36 ± 0.07 กรัม คาร์โบไฮเดรต 66.90 ± 0.25 กรัม ไขมัน 13.30 ± 0.17 กรัม ความชื้น 5.63 ± 0.04 กรัม เถ้า 1.98 ± 0.16 กรัม และพลังงานรวม 435.21 ± 0.34 กิโลแคลอรีต่อ 100 กรัม ผลการศึกษานี้แสดงให้เห็นว่าการเติมเนื้อปูทะเลร้อยละ 5 เป็นระดับที่เหมาะสมในการพัฒนาผลิตภัณฑ์วaffleฟิลกรอบ โดยให้คุณภาพทางประสาทสัมผัสและคุณสมบัติทางกายภาพและเคมีที่เหมาะสม

คำสำคัญ: วaffleฟิล, ปูทะเล, วaffleฟิลกรอบผสมปูทะเล

Abstract

This study aimed to develop a crispy mud crab waffle product. The study evaluated basic waffle formulations and their sensory attributes, including appearance, color, aroma, flavor, texture, and overall acceptability, using 50 participants and a 7-point hedonic scale. The results showed that Formulation 1 achieved the highest acceptability, with mean scores of 5.60 ± 0.99 , 5.70 ± 0.98 , 5.35 ± 0.98 , 5.70 ± 1.16 , 5.90 ± 1.10 , and 5.78 ± 0.97 for the respective attributes. Subsequently, the effects of mud crab meat incorporation at 5%, 10%, and 15% (w/w) were investigated. The formulation containing 5% mud crab meat demonstrated the highest acceptability, with mean scores of 6.33 ± 0.60 , 6.00 ± 0.98 , 6.03 ± 0.92 , 5.94 ± 0.91 , 5.78 ± 0.88 , and 6.03 ± 0.85 for the respective attributes. The selected formulation was further analyzed for its physicochemical properties. The results showed a water activity (a_w) of 0.50 ± 0.01 , color values of $L^* = 51.44 \pm 0.23$, $a^* = 6.30 \pm 0.12$, and $b^* = 43.32 \pm 0.17$, and a crispness value of 5.77 ± 0.24 N. The proximate composition per 100 g revealed 12.36 ± 0.07 g of protein, 66.90 ± 0.25 g of carbohydrates, 13.30 ± 0.17 g of fat, 5.63 ± 0.04 g of moisture, 1.98 ± 0.16 g of ash, and a total energy of 435.21 ± 0.34 kilocalories. These findings indicate that 5% mud crab meat is the optimal incorporation level for crispy waffle development, providing acceptable sensory quality and desirable physicochemical properties.

Keywords: Waffles, Mud crab, Crispy mud crab waffles

1. Introduction

The mud crab, *Scylla serrata* (Forsskål), is widely recognized for its unique sensory attributes and rich nutritional profile. Owing to its culinary versatility, it is widely accepted among domestic and international consumers. Additionally, *S. serrata* constitutes a significant export commodity, particularly in high-demand markets such as Hong Kong, Singapore, Malaysia, and the United States (Thotsaporn et al., 2009). In Thailand, the mud crab represents an important aquatic resource with substantial economic value, especially in Khao Din Subdistrict, Bang Pakong District, Chachoengsao Province. In this area, mud crab production provides supplementary income for local households during agricultural off-seasons, and the crabs can be processed into various value-added food products (Lalida et al., 2020).

Waffles are widely consumed bakery products produced in a variety of textures. Their main ingredients typically include wheat flour, sugar, eggs, and milk (Laddawan et al., 2022). Traditionally, waffles are produced in circular or square shapes and are characterized by a distinctive honeycomb pattern. In the commercial markets, waffle products are often developed as thin and crispy snacks (Kannika et al., 2019).

However, research on the development of value-added snack products from the mud crab, particularly crispy bakery-type products, remains limited. Due to the lack of scientific evidence, this study aims to investigate the effects of incorporating low-grade mud crab raw materials on the quality attributes of crispy waffles, thereby enhancing the value of these underutilized resources.

2. Materials and methods

This study aimed to develop a crispy waffle product incorporated with mud crab meat. The methodology involved optimizing the crab meat ratio within a classic formulation base, and conducting a comprehensive analysis of the product's physical and chemical components. The specific procedures are detailed below.

2.1 Crispy Waffle Sample Preparation

Three crispy waffle formulations, which differed in their ingredient compositions, were prepared to determine the most acceptable formulation. The samples were subjected to sensory evaluation based on appearance, aroma, taste, texture, and overall acceptability. A 7-point hedonic scale was used to evaluate the samples by 50 untrained panelists selected from Khao Din Subdistrict. The formulations are presented in Table 1, and the processing steps are illustrated in Figure 1.

The experiment was designed using a Randomized Complete Block Design (RCBD). Data were analyzed using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) to determine significant differences among treatments. All statistical analyses were performed using statistical software applications.

Table 1. Recipe composition of Basic Crispy Waffle

Ingredients	Amount (%)		
	Formulation 1	Formulation 2	Formulation 3
Cake flour		25.35	17.80
All-purpose wheat flour	18.68		
Cornstarch		5.85	3.55
Chicken eggs	24.28	12.68	23.13
Salt		0.97	0.60
Sugar	12.45	9.75	11.86
Melted unsalted butter	6.23	7.79	5.95
Fresh milk	37.35	11.69	35.58
Water	-	23.39	-
Baking powder	0.38	0.58	0.35
Vanilla flavoring	0.63	1.95	1.18

Reference: Recipe 1. (Sunpech et al.,2022) 2. (Klinsukon et al.,2023) 3. (Jatupol et al.,2020)

2.2 Optimizing Amounts of Mud Crab Meat in Crispy Waffle Products

The study investigated three levels of mud crab meat to identify the optimal amount for crispy waffle production. In all experimental treatments, dried mud crab meat with a water activity (a_w) value of 0.40 was mixed into the cake flour at inclusion levels of 5%, 10%, and 15% of the flour weight. Table 2 summarizes the specific formulation used, while Figure 2 illustrates the production process for the crispy mud crab waffles. The products were subjected to sensory evaluation for appearance, color, aroma, flavor, texture, and overall acceptability using a 7-point hedonic scale. The evaluation was conducted with 50 participants selected from the population and sample group in Khao Din Subdistrict.

A randomized complete block design (RCBD) was employed for the experimental layout. Data were analyzed using Analysis of Variance (ANOVA) to determine the significance of the main effects, and Duncan's New Multiple Range Test (DMRT) was used to compare treatment means. All statistical analyses were conducted using commercial statistical software.

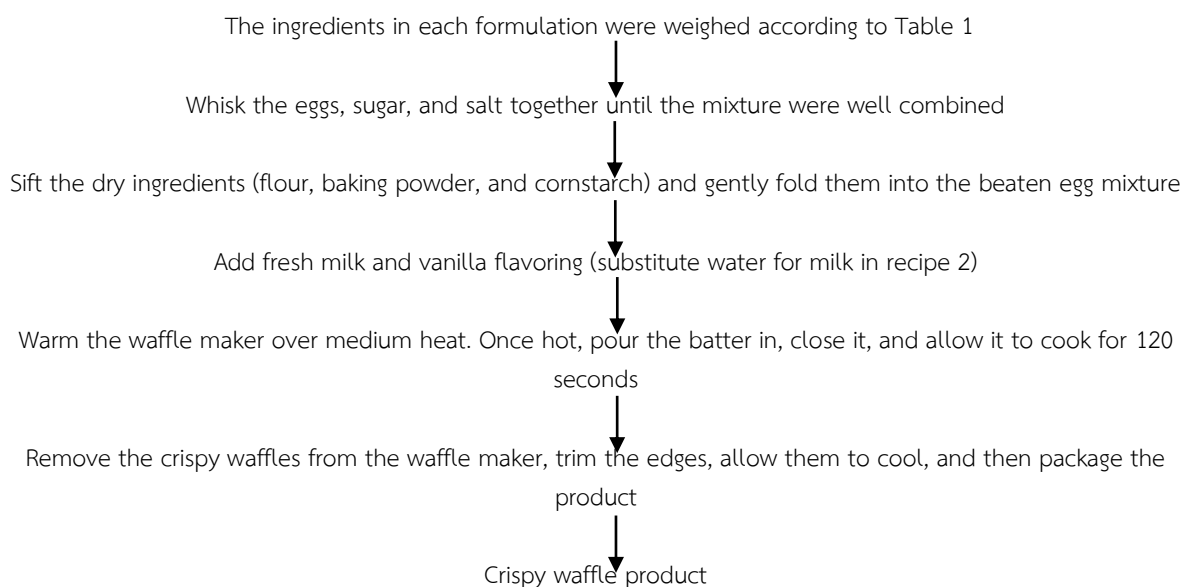


Figure 1. Crispy Waffle Processing

Table 2. Amounts of Mud Crab Meat

Formulation	Meat Proportion (%)
1	5
2	10
3	15

2.3 Analysis of Physicochemical Properties of Crispy Mud Crab Waffles

The formulation with the highest sensory acceptability was selected for further analysis of its physicochemical properties. The physical properties evaluated included water activity (a_w), color values (L^* , a^* , and b^*), and texture (crispness). The chemical composition was analyzed for its protein, carbohydrate, fat, moisture, ash, and energy contents. All analyses were performed in triplicate.

3. Results

3.1 Basic recipes of Crispy Waffles

In this experiment, three basic crispy waffle formulations with differing ingredient compositions were examined to determine the most suitable formulation. The test samples of each formulation are presented in Table 1, and the production procedure is illustrated in Figure 1. Sensory evaluations were conducted, and the mean sensory quality scores of the classic crispy waffle formulations are shown in Table 3.

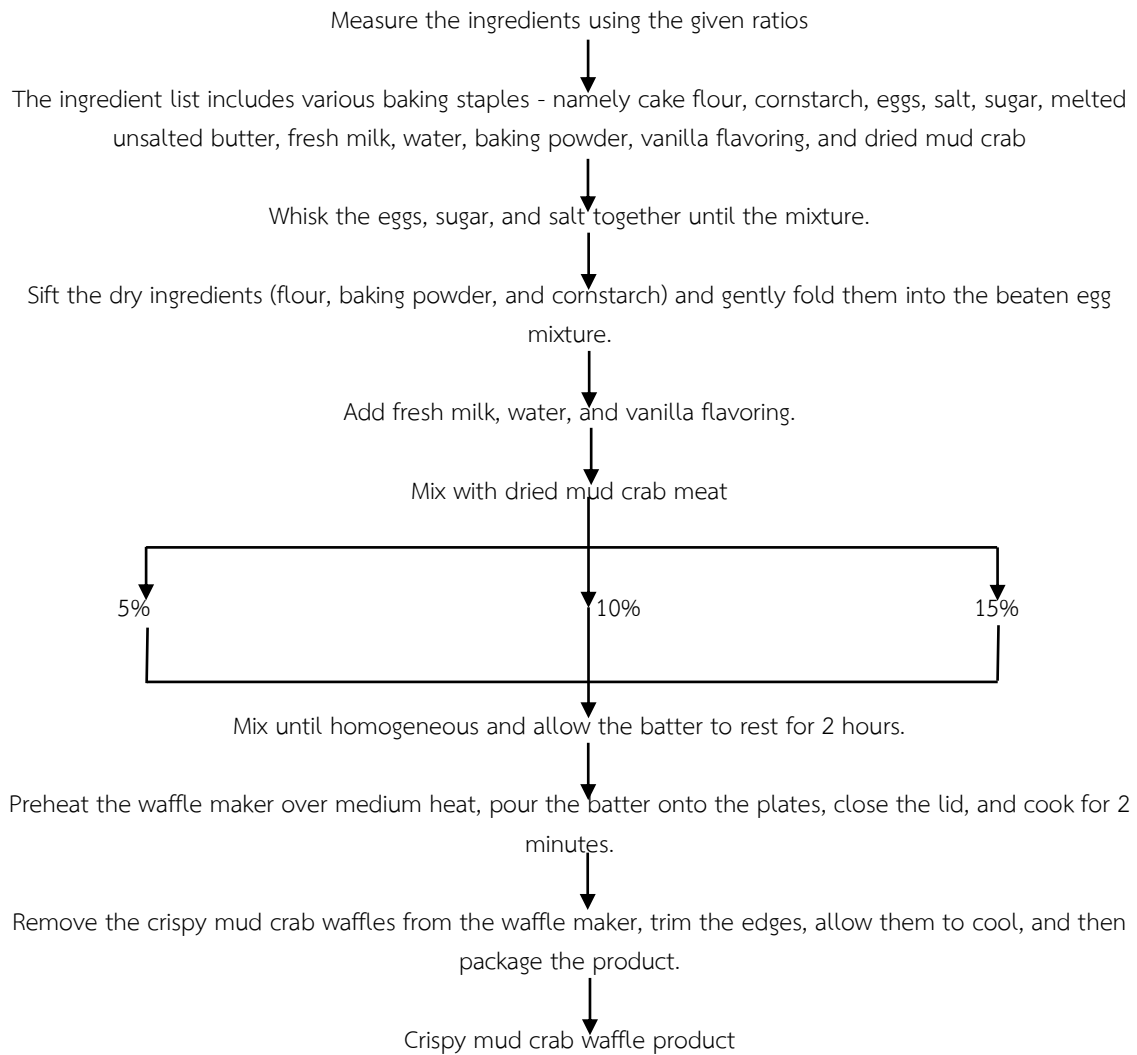


Figure 2. the production process for the crispy mud crab waffles

Table 3. Sensory Evaluation Results of the basic crispy waffle

Sensory parameters	Mean $\pm$ SD		
	Formulation 1	Formulation 2	Formulation 3
Appearance	4.60 $\pm$ 0.88 ^b	5.60 $\pm$ 0.74 ^a	3.63 $\pm$ 1.43 ^c
Color ^{ns}	5.30 $\pm$ 0.99	5.70 $\pm$ 1.16	5.33 $\pm$ 1.31
Aroma ^{ns}	5.28 $\pm$ 0.99	5.35 $\pm$ 0.98	5.18 $\pm$ 1.32
Flavor	5.40 $\pm$ 1.22 ^a	5.70 $\pm$ 0.67 ^a	4.40 $\pm$ 1.34 ^b
Texture	5.33 $\pm$ 1.14 ^b	5.90 $\pm$ 1.10 ^a	4.85 $\pm$ 1.55 ^b
Overall Acceptability	5.43 $\pm$ 1.11 ^a	5.78 $\pm$ 0.97 ^a	4.75 $\pm$ 1.46 ^b

Note: Means within the same row followed by different letters are significantly different ($p < 0.05$)

The results in Table 3 show that ingredient proportions significantly affect sensory attributes. Formulation 2 achieved the highest scores for flavor, aroma, and texture, resulting in the highest overall acceptability. In contrast, Formulation 3 showed lower scores across all sensory attributes, resulting in the lowest overall acceptability. Although Formulation 1 received the highest score for color, it was outperformed by Formulation 2 in most attributes. Overall, the results indicate that Formulation 2 was the optimal Formulation for sensory quality.

3.2 Optimal Level of Mud Crab Meat in Crispy Waffles

In this study, three levels of mud crab meat incorporation (5%, 10%, and 15% w/w) were evaluated based on flour weight. The formulations are presented in Table 2, and the production process is illustrated in Figure 2. All samples were evaluated for sensory attributes to determine the optimal level of crab meat. The mean sensory scores of crispy waffles at different levels of incorporation are summarized in Table 4.

As shown in Table 4, the results indicate that different levels of crab meat significantly affect sensory attributes. The formulation containing 5% crab meat showed the highest scores across all attributes. In contrast, the formulations containing 10% and 15% crab meat showed lower scores, with the 15% level resulting in the lowest values, particularly in texture and flavor. These results indicate that incorporating mud crab meat at 5% provides the optimal sensory quality for crispy waffle products.

Table 4. Sensory evaluation of crispy waffle with different amounts of mud crab crispy waffle products

Sensory parameters	Mean $\pm$ SD		
	5%	10%	15%
Color	6.33 $\pm$ 0.60	5.83 $\pm$ 1.01	5.26 $\pm$ 0.82
Aroma	6.00 $\pm$ 0.98	5.23 $\pm$ 1.07	5.16 $\pm$ 0.79
Flavors	6.03 $\pm$ 0.92	5.23 $\pm$ 0.67	5.81 $\pm$ 1.04
Texture	5.94 $\pm$ 0.91	5.26 $\pm$ 0.63	4.33 $\pm$ 1.06
Appearance	5.78 $\pm$ 0.88	5.36 $\pm$ 1.06	5.16 $\pm$ 0.69
Overall Acceptability	6.03 $\pm$ 0.85	5.26 $\pm$ 0.69	5.23 $\pm$ 1.04

Note: Means within the same row followed by different letters are significantly different ($p < 0.05$)

3.3 Evaluation of the Quality of Crispy Mud Crab Waffle Products

The formulation with the highest sensory acceptability, based on the sensory evaluation (Table 4), was selected for further analysis of its physicochemical properties. All analyses were performed in triplicate, and the results are presented in Table 5.

Table 5. Physicochemical Properties of Crispy Mud Crab Waffles

Parameters	Values
Physical Components	
Water Activity (a_w)	0.50 ± 0.01
Lightness (L^*)	51.44 ± 0.23
Redness (a^*)	6.30 ± 0.12
Yellowness (b^*)	43.32 ± 0.17
Textures (Crispness)	$5.77 (N) \pm 0.24$
Chemical Composition (g/100 g)	
Protein	12.36 ± 0.07
Carbohydrates	66.90 ± 0.25
Lipids (Fats)	13.30 ± 0.17
Moisture (Water)	5.63 ± 0.04
Ash (Minerals)	1.98 ± 0.16
Energy (kcal/100 g)	435.21 ± 0.34

Note: A higher L^* is a measure of greater lightness, Positive a^* is a measure of redness, while negative a^* is a measure of greenness, Positive b^* is a measure of yellowness, whereas negative b^* is a measure of blueness

Table 5 shows that the crispy mud crab waffle had a water activity (a_w) of 0.50 and a moisture content of 5.63%, indicating good product stability and a crispy texture, as supported by the texture (crispness) value (5.77 N). The L^* , a^* , and b^* values indicate that the product exhibited a yellowish color with moderate lightness.

In terms of proximate composition, the product contained 12.36% protein, 66.90% carbohydrates, and 13.30% fat, with an energy value of 435.21 kcal/100 g. The ash content (1.98%) suggests the presence of mineral components derived from the raw materials.

Overall, the crispy mud crab waffle demonstrated acceptable physicochemical properties, characterized by a crispy texture and balanced composition.

4. Discussion

As shown in Table 3, the test sample of Formulation 2 received the highest mean scores across the key sensory attributes—aroma, taste, texture, appearance, and overall acceptability. This can be attributed to the fact that Formulation 2 contained the highest proportion of corn flour, which contributed to a crispier texture. This result is supported by Sunthon et al. (2017) who reported that incorporating corn flour into snack formulations containing purple rice and corn flour enhanced product crispness.

Based on these results, the test sample of Formulation 2 was identified as the most suitable candidate for further testing aimed at establishing the optimal proportion of dried mud crab meat for the crispy waffle product.

Table 4 shows that a 5% inclusion level of mud crab meat yielded the highest mean sensory scores, indicating it to be the most appropriate amount for the crispy waffle product. As the percentage of crab meat increased, the moisture content also rose, which negatively affected the expansion of the waffle. This observation supports the work of Jeeranan et al., (2024), who found that increasing rice-field crab content in seasoned rice crackers reduced product expansion.

In addition to the increased moisture content, the higher amount of crab meat affected the dispersibility of the waffle batter. It was observed that the waffle batter containing a higher crab content spread less when placed inside the waffle iron. This result was consistent with the findings of Patcharalak et al., (2025), who developed crispy waffles enriched with pink oyster mushroom powder. Their study indicated that the fibrous structure of the powder enhanced the water-holding capacity (WHC), which limited batter spread during cooking and produced thicker waffles.

In the quality assessment of the crispy mud crab waffle that received the highest sensory acceptability, it was found that the product had a water activity (a_w) of 0.50 and a moisture content of 5.63%. These values produced a desirable crispness. According to Khanittha et al., (2025), the quality standard for dehydrated foods requires a water activity (a_w) below 0.6. As reported in their study “Characterization of Enzyme-Extracted Rice Bran Protein Powder and Its Application in Protein-Enriched Jelly,” Microbial growth is inhibited and controlled under these conditions, a process that correlates strongly with the measured crispness value of 5.77 N.

The color values (L^* , a^* , b^*) reflected moderate lightness with a dominant yellow tone, which is characteristic of dried baked products. The proximate composition showed that the product contained 66.90% carbohydrates, 12.36% protein, and 13.30% fat, providing an energy value of 435.21 kcal per 100 g, aligning with typical starch-based crispy snack formulations.

Overall, the findings indicated that the test sample of formulation 2 with the addition of 5% mud crab meat was identified as the most suitable formulation, delivering superior sensory performance and appropriate physical and chemical attributes. This outcome highlighted the product’s viability for further industrial production.

5. Conclusions and recommendations

The results of this study showed that Formulation 2 with 5% mud crab meat incorporation was the optimal formulation, demonstrating high sensory acceptability and acceptable physicochemical properties.

Future research should focus on improving the nutritional profile of the product, particularly by increasing its dietary fiber content. In addition, further studies should investigate shelf-life stability, texture changes during storage, and the effects of processing conditions on product quality. The development of standardized quality control and processing protocols is also recommended to support consistent product quality and scalability.

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