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# Gluten-free crackers supplemented with cricket (*Gryllus bimaculatus*) powder

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**Abstract**

The production of gluten-free cracker enriched with cricket powder had two drying conditions, that was oven drying and vacuum drying, and replacement levels of cricket powder at 10%, 20%, and 30% of the weight of rice flour. It was found that cricket powder which was obtained from vacuum drying had higher protein content, ash content, and L*, b* values compared to cricket powder which was obtained from oven drying. The physical properties were observed that increasing the amount of cricket powder in the product resulted in an increase in width expansion, while thickness and hardness decreased. Additionally, the L* value decreased due to the dark brown color of cricket powder, resulting in a darker appearance of the crackers. Regarding sensory evaluation, overall liking of the cracker supplemented with cricket powder from oven drying and 20% replacement level was the highest and did not significant difference ($p$>0.05) from the control. Moreover, the hardness also was similar. When compared to the chemical composition of the control formula, the cracker supplemented with cricket powder from oven drying at 20% showed higher levels of protein, fat, fiber, and ash content. This cracker can be considered as an option for general consumers and those with gluten allergies who are looking for a protein-rich alternative.

**Keywords**: Cracker, Cricket, Gluten-free, Protein

## 1. Introduction

Over the past 5 years, the consumption of insects has become increasingly interesting for modern consumers, growing rapidly due to insects being considered an alternative food source with high protein content. In addition to high protein, insects also contain low-fat content, vitamins, minerals, and fiber from chitin [1]. Moreover, insect-based food contributes to sustainability as it has a lower environmental impact compared to meat or other animal-based sources, requiring less water and emitting fewer greenhouse gases [2].

The Food Ingredients Asia event in 2020 highlighted emerging trends in the food and beverage industry, particularly the rising popularity of alternative and novel protein sources such as cricket protein. At the time, the cricket protein market was valued at approximately 6.725 billion baht and was expected to grow by 6.4%, driven largely by its use in insect-based meat substitute products [3].

Crickets have 63% protein, surpassing the protein content of beef, chicken, and even certain plant-based proteins [4]. The protein is composed of essential amino acids such as valine, leucine, and lysine [5]. Additionally, crickets contain lipids (20.40-29.30%) and carbohydrates (5.50-8.32%), as well as the antioxidant 2,2-diphenyl-1-picrylhydrazyl (DPPH) at 1.1528 mg/mL [6].

Turning insects into powder is one way to address the negative perception of eating insects and marks the beginning of developing new food products that incorporate insects as ingredients. When using cricket powder in food products, such as bakery items, it provides an opportunity to enhance nutritional value with ingredients like flour, cheese, and sugar. Products like bread, cakes, cookies, muffins, cereal bars, and crackers can benefit from

cricket powder incorporation [7-8]. Gluten-free crackers, which include cricket powder, serve as an option to increase nutritional value, especially for those allergic to gluten or seeking additional protein [9].

Crackers, a type of baked products, primarily consist of wheat flour, resulting in a crisp and firm texture suitable for various occasions. They can be consumed as snacks or main meals and can be used to create other desserts. Crackers are divided into three types: soda crackers, snack crackers, and flavored crackers [10]. Today, crackers are produced in various flavors, both savory and sweet, often fortified with additional nutrients to increase their nutritional value.

As an example, a study by Machado et al. [11] investigated the addition of cricket powder to gluten-free bread at two levels: 10% and 20%. The results showed that adding 10% cricket powder increased the protein content by 47% compared to the control recipe. Commercially available cereal bars containing cricket powder were found to have a 14% cricket powder content [6]. In cereal bars, cricket powder can replace plant-based ingredients up to 15% [12].

For consumers seeking healthier snacks with low fat, low salt, and no or minimal cholesterol, the challenge for researchers is to develop gluten-free products with high protein content. It is essential to meet the sensory preferences of consumers while maintaining nutritional quality. The overall goal is to provide a nutritious and appealing alternative for individuals with gluten intolerance or those pursuing a healthy lifestyle. The market for gluten-free products grew by 27% from 2001 to 2010, indicating a rising demand for these alternatives [8]. In this research, the objective is to substitute rice flour with cricket (*Gryllus bimaculatus*) powder in gluten-free cracker products. The cricket-enriched crackers were produced from low-grade crickets, combined with rice flour, offer such an alternative and add value to cricket powder. The physical, chemical, and sensory properties of these cricket powder-enriched crackers will be studied.

## 2. Materials and methods

### *2.1 Raw materials*

Frozen crickets were obtained from Sivaphon Farm in Chumpae District, Khon Kaen Province, Thailand**.** Other ingredients were provided from supermarkets in Nong Khai Province, Thailand**.**

### *2.2 Cricket powder and crackers preparation*

The frozen crickets were thawed and uniformly spread on a sieve. They were then vacuum dried at 55ºC for 6 h and oven dried at 60ºC for 48 h. The dried crickets were ground into powder using a fine grinder and screened through a 200-mesh sieve to obtain cricket powder. and stored at 4ºC for further experiments.

Rice flour, Vanilla powder, and baking powder were mixed and set aside. Butter, icing sugar, and salt were beaten together at medium speed for 5 min, followed by reducing the speed. The ground cricket powder (instead rice flour 0, 10, 20 and 30%), milk, and water were added and beaten until the mixture formed a cohesive ball [13]. The dough was rolled into thin sheets, and circular shapes were cut using a mold (5 cm diameter, 3 mm thickness). These were then placed on a silicone-lined tray and baked at 160ºC for 16 min. After baking, the crackers were cooled on a rack, placed in PE plastic bags, and stored in a refrigerator for further analysis.

### *2.3 Crackers analysis*

#### *2.3.1 Chemical analysis*

Chemical analysis of cricket powder and crackers was conducted for moisture, fat, protein, ash, fiber, and carbohydrates content using AOAC standard methods [14].

Moisture analysis- Crackers (3 g each) and cricket powder were weighed, oven-dried at 105ºC for 24 h, and then the final weight was recorded. The weight was measured to calculate the percentage of moisture content in each sample. The experiment was repeated 3 times.

Fat analysis- Crackers and cricket powder samples were oven-dried to remove moisture. The fat was extracted using petroleum ether in a Soxhlet apparatus. The weight of the samples before and after extraction was measured to determine the fat content. After extraction, the solvent was evaporated, and the fat was oven-dried for moisture removal. The weight was then measured to calculate the percentage of fat in each sample. The experiment was repeated three times.

Cracker and cricket powder samples were analyzed using the Kjeldahl method. The samples were digested with concentrated sulfuric acid, then distilled and titrated to determine their nitrogen content. Protein content was

calculated by multiplying the nitrogen content by a conversion factor. For the cracker samples, a standard nitrogen-to-protein conversion factor of 6.25 was used. However, for the cricket powder, some researchers have argued that the 6.25 factor may overestimate protein content and have recommended using a factor of 5.33 instead [15]. The experiment was conducted in triplicate.

Fiber analysis- Samples, after fat extraction, were further reduced using sulfuric acid and hydrochloric acid. The remaining fibers were washed with acetone, oven-dried, and weighed to calculate the percentage of crude fiber. The experiment was repeated three times.

Ash analysis- Crackers and cricket powder were incinerated at 550°C to obtain ash. The ash was weighed, and the percentage of ash content in the dry weight was calculated. The experiment was repeated three times.

*2.3.2 Physical analysis*

Expansion ratio measurement of cricket crackers- The expansion ratio of the crackers was measured using a Vernier caliper (mm). The width and thickness expansion percentages were calculated using the formulas:

Width (%) = (Width after baking - Width before baking) / (Width before baking) * 100

Thickness (%) = (Thickness after baking - Thickness before baking) / (Thickness before baking) * 100

Hardness measurement of cricket crackers- The hardness of the crackers was measured using a texture analyzer with a cutting head. The test was conducted under pre-test, test, and post-test conditions at speeds of 1.5, 2, and 10 mm/s, respectively. The hardness was recorded in Newtons (N) for 10 repetitions.

Color measurement of cricket crackers and cricket powder- The color of the seven formulations of crackers and cricket powder was measured using a colorimeter. Three parameters were recorded: L* (lightness), a* (red/green), and b* (yellow/blue). The experiment was repeated three times.

*2.3.3 Sensory evaluation*

A panel of 30 general consumers (students from Khon Kaen University, Nong Khai Campus) evaluated the acceptance of cricket crackers on a 9-point Hedonic Scale, rating attributes such as color, appearance, flavor, texture and overall liking.

*2.4 Statistical analysis*

The cricket powder data were statistically analyzed using a t-test. One-way ANOVA was used to assess statistical variations, and Duncan's Multiple Range Test was applied to compare the cracker samples under two conditions at a confidence level of $p < 0.05$.

## 3. Results and discussions

*3.1 Chemical and color analysis of cricket powder components*

From Table 1, it was found that cricket powder from both drying methods has significantly different quantities of fat, protein, ash, and carbohydrates ($p<0.05$). Vacuum-dried cricket powder has higher protein and ash quantities than oven-dried cricket powder, while the latter has lower fat and carbohydrate values. This difference was attributed to variations in the drying temperature. The protein, fat, and carbohydrate quantities are close to those found in *Acheta domesticus* studied by Pilco-Romero et al. [16] but lower in protein and fiber and higher in fat than cricket powder studied by Machado et al. [10], which had protein, fiber, and fat values of 62.76, 8.42, and 20.96, respectively. This aligns with the research of Ribeiro et al. [12], which found that using freeze-drying or microwaving techniques maintained the nutritional value of cricket powder more effectively than using an oven due to differences in temperature and duration. The L*, a*, and b* values of cricket powder from the vacuum drying are significantly higher than those from the oven drying ($p<0.05$).

**Table 1** Chemical analysis and color of cricket powder.

| Cricket powder | Oven | Vacuum oven |
|---|---|---|
| Moisture content (wb) | 2.60±0.16[a] | 3.26±0.52[a] |
| Fat (db) | 27.96±0.24[a] | 26.85±0.24[b] |
| Protein (db) | 53.95±0.21[b] | 57.80±0.08[a] |
| Fiber (db) | 10.00±0.24[a] | 10.34±0.20[a] |
| Ash (db) | 3.05±0.04[b] | 3.31±0.02[a] |
| Carbohydrates (db) | 5.03±0.28[a] | 1.69±0.39[b] |
| L* | 23.40±1.22[b] | 27.86±0.60[a] |
| a* | 5.35±0.04[b] | 5.86±0.01[a] |
| b* | 9.02±0.10[b] | 9.72±0.11[a] |

The letters that differ in the row indicate statistically significant differences ($p$<0.05).

### *3.2 Expansion ratio of crackers*

From Figures 1 and 2, it can be observed that supplementing cricket powder at 10%, 20%, and 30% levels increases the width expansion ratio while decreasing the thickness expansion ratio. This is because cricket powder has a relatively high fat content, reducing water absorption and resulting in increased width expansion with higher powder levels. Using cricket powder with different drying methods at the same level does not significantly impact the width and thickness of crackers.

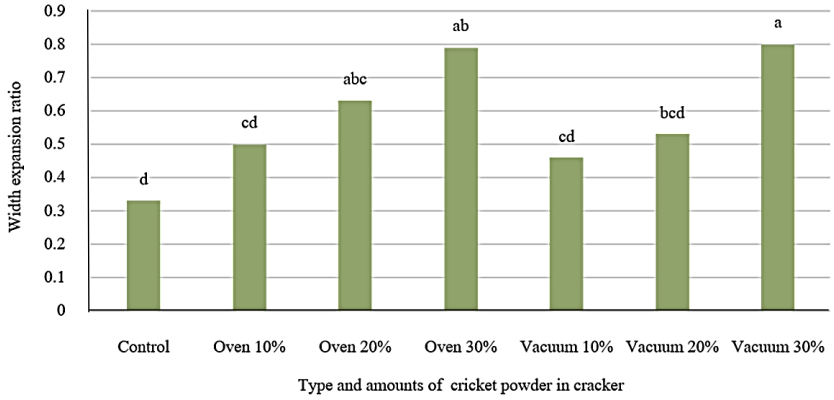


**Figure 1** Width expansion ratio of cracker supplemented with cricket powder.
Different letters on the bars indicate statistically significant differences ($p$<0.05).

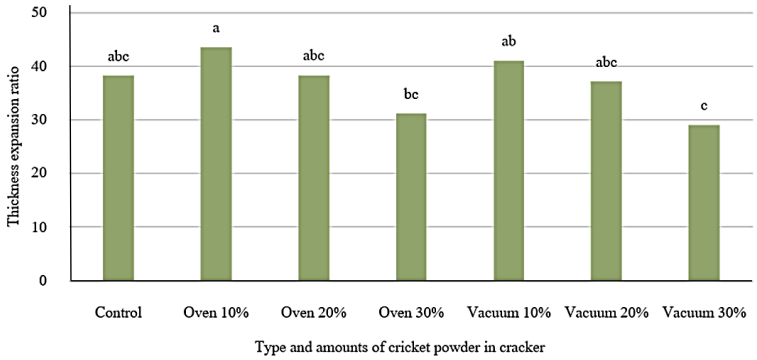


**Figure 2** Thickness expansion ratio of cracker supplemented with cricket powder.
Different letters on the bars indicate statistically significant differences ($p$<0.05).

*3.3 Hardness of crackers*

From Figure 3, it is evident that increasing the cricket powder quantity results in increased hardness due to higher protein content [11]. However, as the level of cricket powder increases, the hardness decreases because the added powder reduces the elasticity of the cracker, resulting in decreased hardness. Interestingly, cricket powder levels at 20% and 30% with oven drying and 30% with vacuum drying did not show significant differences in hardness compared to the control formula ($p<0.05$). This aligns with the findings for cricket crackers (*Acheta domesticus*) supplemented with 20% cricket powder, which showed increased hardness with higher cricket powder levels but decreased hardness at 30% [17].

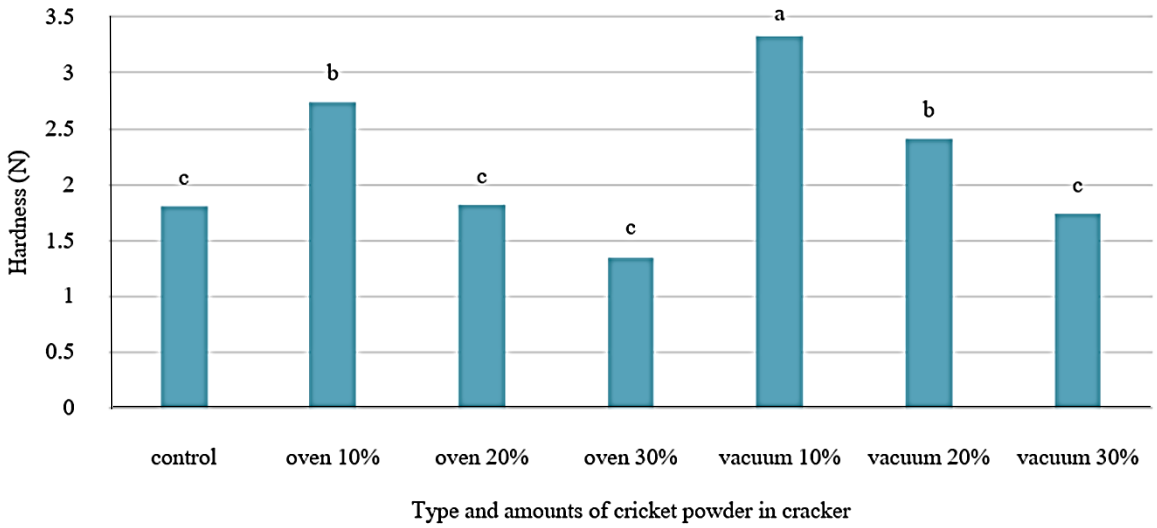


**Figure 3** Hardness of cracker supplemented with cricket powder.
Different letters on the bars indicate statistically significant differences ($p<0.05$).

*3.4 Color of cricket powder components*

From Table 2, it was observed that increasing cricket powder results in decreased lightness (L*) and yellowness (b*) values while increasing redness (a*) values in crackers. This is attributed to the dark brown color of cricket powder. The all of crackers supplemented with cricket powder were significant difference from the control formula ($p<0.05$).

**Table 2** Color of cracker supplemented with cricket powder.

| Cracker | L* | a* | b* |
|---|---|---|---|
| Control | $77.46\pm0.36^{a}$ | $2.72\pm0.34^{d}$ | $19.42\pm1.35^{a}$ |
| Oven 10% | $64.30\pm0.45^{c}$ | $4.28\pm0.20^{c}$ | $14.19\pm0.26^{bc}$ |
| Oven 20% | $58.87\pm1.04^{e}$ | $5.09\pm0.24^{b}$ | $14.81\pm0.80^{b}$ |
| Oven 30% | $56.48\pm0.58^{f}$ | $5.13\pm0.15^{b}$ | $13.60\pm0.39^{bcd}$ |
| Vacuum 10% | $67.71\pm0.37^{b}$ | $4.13\pm0.06^{c}$ | $13.00\pm0.23^{cd}$ |
| Vacuum 20% | $60.75\pm0.96^{d}$ | $4.79\pm0.22^{b}$ | $12.67\pm0.54^{d}$ |
| Vacuum 30% | $54.42\pm0.27^{g}$ | $5.67\pm0.23^{a}$ | $13.18\pm0.64^{cd}$ |

The letters that differ in the column indicate statistically significant differences ($p<0.05$).

*3.5 Sensory evaluation*

From Table 3, sensory testing involving 30 participants in the Khon Kaen University, Nong Khai Campus area reveals that the color, appearance, flavor, texture, and overall liking of crackers supplemented with cricket powder. This study aimed to maximize the protein content in crackers by incorporating cricket powder. Crackers made with 30% cricket powder using vacuum drying showed decreased consumer preference across all attributes. Therefore, the optimal level was determined to be 20% cricket powder. Additionally, when comparing the two drying methods, no significant difference in consumer liking was observed ($p<0.05$). Overall, consumer acceptance ranged from neutral to slightly liked. Since oven drying has a lower production cost, it was selected for further analysis of the crackers' chemical composition. These results were consistent with the study by Suga et al. [17] on cricket crackers supplemented with 20% cricket powder.

**Table 3** Sensory evaluation of crackers supplemented with cricket powder.

| Cracker | Color | Appearance | Flavor | Texture | Overall |
|---|---|---|---|---|---|
| Control | $6.27\pm0.26^{a}$ | $6.20\pm0.23^{a}$ | $6.37\pm0.25^{a}$ | $4.27\pm0.31^{c}$ | $5.20\pm0.26^{ab}$ |
| Oven10% | $5.83\pm0.24^{ab}$ | $5.87\pm0.25^{ab}$ | $6.03\pm0.25^{ab}$ | $5.7\pm0.35^{a}$ | $5.87\pm0.31^{a}$ |
| Oven20% | $5.7\pm0.26^{ab}$ | $5.8\pm0.22^{ab}$ | $6.17\pm0.24^{ab}$ | $5.5\pm0.25^{ab}$ | $5.57\pm0.20^{ab}$ |
| Oven30% | $5.93\pm0.17^{ab}$ | $5.8\pm0.25^{ab}$ | $5.4\pm0.24^{bc}$ | $5.3\pm0.32^{ab}$ | $5.43\pm0.28^{ab}$ |
| Vacuum10% | $5.57\pm0.23^{ab}$ | $5.83\pm0.23^{ab}$ | $5.7\pm0.27^{abc}$ | $4.70\pm0.32^{bc}$ | $5.40\pm0.27^{ab}$ |
| Vacuum20% | $5.83\pm0.25^{ab}$ | $5.73\pm0.20^{ab}$ | $5.67\pm0.25^{abc}$ | $5.43\pm0.31^{ab}$ | $5.57\pm0.27^{ab}$ |
| Vacuum30% | $5.23\pm0.28^{b}$ | $5.33\pm0.29^{b}$ | $5.17\pm0.26^{c}$ | $4.67\pm0.35^{bc}$ | $4.80\pm0.28^{b}$ |

The letters that differ in the column indicate statistically significant differences ($p<0.05$).

*3.6 Chemical composition of crackers*

Chemical analysis of cricket crackers supplemented with 20% cricket powder from oven drying, compared to control crackers, shows significant differences in moisture, fat, protein, fiber, ash and carbohydrate content. Cricket crackers exhibit increased protein, fat, fiber, and ash due to the high content of these components in cricket powder. The protein and fat quantities are close to those in cricket powder supplemented bread with 20% cricket powder (12.52% protein) [11] and cereal bar with 15% cricket powder (12-13% protein) [12].

**Table 4** Chemical composition of cracker supplemented with cricket powder.

| Cracker | Control | Oven 20% cricket powder |
|---|---|---|
| Moisture content (wb) | $4.92\pm0.01^{a}$ | $3.66\pm0.08^{b}$ |
| Fat (db) | $15.46\pm0.91^{b}$ | $18.86\pm0.40^{a}$ |
| Protein (db) | $6.15\pm0.38^{b}$ | $11.16\pm0.19^{a}$ |
| Fiber (db) | $0.28\pm0.03^{b}$ | $1.31\pm0.04^{a}$ |
| Ash (db) | $1.20\pm0.06^{b}$ | $1.34\pm0.02^{a}$ |
| Carbohydrates (db) | $76.89\pm0.83^{a}$ | $67.31\pm0.31^{b}$ |

The letters that differ in the row indicate statistically significant differences ($p<0.05$).

## 4. Conclusions

Cricket powder from vacuum drying has higher protein, fiber, and L*, a*, and b* values compared to cricket powder from oven drying. The addition of cricket powder in crackers results in decreased product hardness and increased darker color. Consumers are satisfied with cricket crackers supplemented with 20% cricket powder from oven drying. Moreover, the obtained cracker had higher protein, fat, fiber and ash content but lower carbohydrate content than cracker without cricket powder.

## 5. Acknowledgements

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