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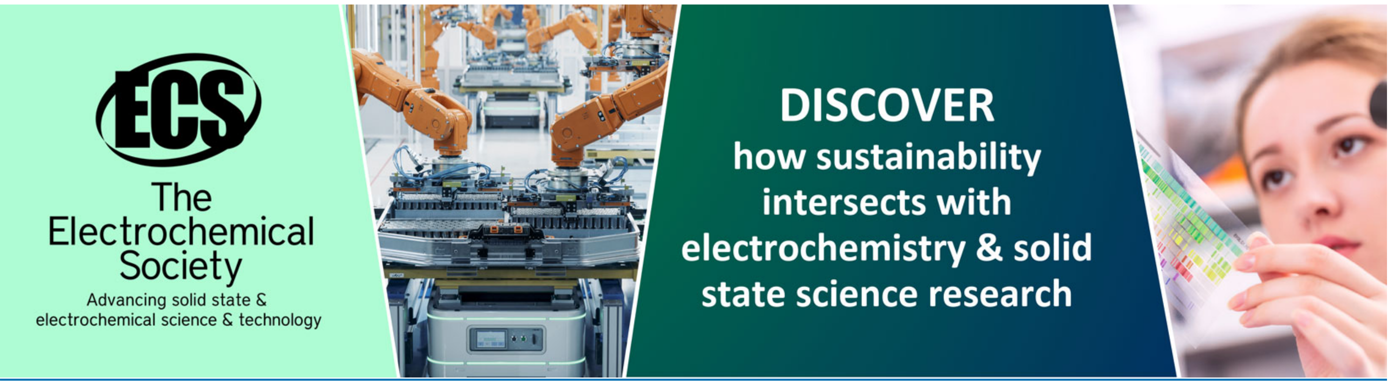

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Development of cricket flour-enriched cookies

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Abstract. The need for high-protein foods strives for the food sector to find an efficiently produced protein sources. One of the most efficient and fast reproducing protein sources are insects containing high levels of protein, nutrients and vitamins. Crickets are one of the most consumed insects, especially in Southeast Asia. Despite the potential of crickets as sources of protein, cricket flour is very little used and studied in Indonesia. This study aimed to develop the best formulation for cricket flour-enriched cookies with a high nutrient and consumer acceptability. As the main ingredient of cookies, wheat was substituted by 5%, 10% and 20% of cricket flour. Among the tested formula, cookies with the 5% and 10% cricket flour showed the highest overall organoleptic acceptability. These cookies are significantly higher in protein and lower in fiber and carbohydrate compared to cookies made with wheat flour.

1. Introduction

Insects are considered as the future foods due to their high nutritional values and rapid reproduction rate. A wide range of edible insect species, with their high contents in proteins, fat, fiber, vitamins and minerals, is believed to play a significant role in addressing food insecurity and environmental destruction linked to classic animal husbandry. Compared to cattle, insects exhibit a significantly higher feed conversion ratio and emit less greenhouse gases. Therefore, the act of eating insects (entomophagy) would not only be beneficial for human health, but also for the environment and economics [1].

House cricket (*Acheta domiscus*) is a type of popular edible insect, especially in the South-East Asian regions. The efficiency of house cricket production is far more efficient than the production of pork and beef. For comparison, the production process to yield 1kg of edible cricket would need 2.1 kg of dried feed while the production of pork and beef would require 9.1 and 25 kg of dried feed respectively. House cricket has a high protein content (20-25 g/100g fresh weight) that is comparable to common sources of protein like beef, egg, or chicken. Besides, house cricket is also rich in B2, B3 and B12 vitamins, as well as other minerals like sodium, phosphorous, calcium, potassium, zinc and iron [2]. One way to implement crickets into food is by processing it into cricket flour. Cricket flour can be used as an alternative for conventional flour due its high protein and nutrient contents [3].

In comparison to other animal proteins (poultry, pig, or beef), insect protein production has lower environmental impacts and a higher economic values. Much less water is required to manufacture protein from insects [4]. Furthermore, substantially smaller quantities of land are required for its production. Another advantage is the ability to use waste products from the agri-food business as feed. It enables the reduction of production-related expenses and the process is independent of the feedstock utilized as human food [5]. Furthermore, such manufacturing produces lesser amounts of hazardous gases to the environment, such as CO_2 or methane. All of these advantages make cricket-based food not only affordable, healthful and useful, but also ecologically benign [6].

Cookies are small, sweet cake typically round and flat made from the mixture of flour, eggs, sugar, fat and other addition that baked until crispy or chewy. Cookies are generally accepted and consumed by a wide range of consumers, particularly those aged 18-24 years old [7]. This study, focusing on the application of cricket flour in the production of cookies for protein fortification, aimed to develop the best formulation for cricket flour-enriched cookies with a higher protein content and consumer acceptability.

2. Methods

2.1. Production of cricket flour
The production of cricket flour was done as previously described [8] with some modifications. The crickets used in this study were wingless juvenile crickets aged 28-30 d old. The crickets were let fast for 9 h prior to freezing at -20°C for 12 h. The frozen crickets were then boiled in demineralized water at 100°C for 5 min prior to oven drying at 90°C for 9 h. The dried crickets were powdered using a blender, sifted to remove unwanted particles (particularly leg fragments) and kept in a sealed airtight glass jar at 4°C prior to utilization in cookie dough.

2.2. Production of cricket flour-enriched cookies
The formulation of cricket flour-enriched cookies was based on a standard recipe book that has been validated by the authors through a series of trial-and-error experiments [9]. Briefly, cricket flour was used to substitute wheat flour (brand "Jawara", Bungasari Flour Mills, Cilegon, Indonesia) to enrich the protein content in cookies. Table 1 represents the formulation of cricket flour-enriched cookies used in this study. All the ingredients were mixed to form cookie dough and tablespoons of the dough were rolled into balls prior to chilling in the fridge (4°C) for 15 min. The balls were then flattened using fingers and placed in the oven at 170°C for 10 min. The cookies were left to cool completely and kept in a sealed airtight glass jar at room temperature prior to the proximate and organoleptic analyses.

Table 1. Formulation of cricket flour (CF)-enriched cookies

Ingredient	Control (0%)	Cookies CF5%	Cookies CF10%	Cookies CF20%
Wheat flour (g)	100	95	90	80
Cricket flour (g)	0	5	10	20
Caster sugar (g)	65	65	65	65
Margarine (g)	60	60	60	60
Chocolate powder (g)	10	10	10	10
Vanilla extract (g)	6	6	6	6
Salt (g)	2	2	2	2
Baking powder (g)	1	1	1	1
Egg	3	3	3	3

2.3. Proximate analysis
The proximate analysis was performed on cricket flour-enriched cookies using standardized methods established by the Association of Official Analytical Chemists (AOAC) and American Oil Chemists Society (AOCS) as previously described [10]. The moisture content was measured by gravimetry following oven-drying at 135°C for 2 h. The ash/mineral content was determined by gravimetry after calcination at 550°C. The fat content was analyzed by gravimetry following sample extraction in Soxhlet apparatus with petroleum ether at 40-60°C. The protein content was analyzed using Kjehldahl method. Total dietary fiber was determined following a series of *in vitro* digestion with human digestive enzymes and ethanol precipitation [11]. The carbohydrate content was obtained by difference.

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2.4. Organoleptic analysis

The organoleptic analysis performed in this study consisted of hedonic rating analysis on 5 different organoleptic parameters of cricket flour-enriched cookies: aroma, color, taste, texture and overall, as previously described [12]. The analysis was done by asking 128 untrained panelists aged 18-45 years old to rate the degree at which they like each parameter using a Likert scale of 1 (do not like it at all) to 9 (like it very much). Commercial chocolate cookies without cricket flour of a well-known brand were used as a comparison.

2.5. Statistical analysis

The data obtained from the chemical and organoleptic analyses were analyzed using software SPSS version 26.0. One-way ANOVA was used to compare the means in all groups of cricket flour-enriched cookies. The difference between two groups was analyzed using post hoc Tukey HSD test at the significance level of 0.05.

3. Results and Discussions

The interest of using insect in food fortification is articulated around its high levels of protein [13]. Indeed, the nutritional profile of cricket flour is significantly different from wheat flour. Compared to wheat flour, cricket flour is characterized by a significantly higher content of protein, fat and ash/mineral (Table 2). Protein and fat in cricket flour were three and nine times as high as the ones in wheat flour. In contrast, carbohydrate and fiber were found to be lower in cricket flour than in wheat flour. In general, cricket flour contains higher levels of essential amino acids compared to wheat flour with an approximate ratio of 5:4 (Table 3). Histidine is found to be at similar levels between cricket flour and wheat flour. Interestingly, cricket flour is lower in phenylalanine compared to wheat flour. In both flour, methionine is the limiting amino acid found in the least amount.

Table 2. The nutritional profile of wheat flour and cricket flour (dry basis)

Parameter	Wheat flour [14]	Cricket flour [15]
Protein (%)	15.1	45.8
Fat (%)	2.73	23.7
Ash/mineral (%)	1.56	4.3
Carbohydrate (%)	71.2	19.6
Fiber (%)	10.6	5.7

Table 3. Essential amino acid profile of wheat flour and cricket flour (dry basis) (n=3)

Essential Amino Acid (mg/g protein)	Wheat flour [16]	Cricket flour [17]
Histidine	23.46±0.36	23.37±0.25
Isoleucine	33.99±0.4	40.91±0.33
Leucine	65.76±0.59	72.09±0.73
Lysine	21.35±0.51	55.84±0.55
Methionine	16.75±1.09	19.67±0.29
Phenylalanine	46.84±0.57	34.68±0.35
Threonine	26.13±0.34	36.84±0.11
Valine	37.97±0.34	59.48±0.46
Total	272.25	342.88

Table 4 shows that the addition of cricket flour in cookies formulation increased significantly the protein and mineral content in the cookies, along with the energy content. In contrast, the fiber and carbohydrate content were lower compared to cookies made from wheat flour. The protein content increased by 1.43%, 3.19% and 5.65% for cookies supplemented with 5%, 10% and 20% of cricket flour respectively. The obtained results were consistent with the findings in previous studies demonstrating improvement in protein content in muffins, buns and sourdough bread made with cricket flour [18-24].

Table 4. Nutritional profile of cricket flour (CF)-enriched cookies (dry basis) (n=3)

Parameter	Control CF0%	Cookies CF5%	Cookies CF10%	Cookies CF20%
Energy per 100 g (kcal)	$484.04^{a}\pm4.32$	$486.18^{b}\pm3.18$	$487.41^{c}\pm3.26$	$493.64^{d}\pm4.21$
Protein (%)	$8.13^{a}\pm0.62$	$9.56^{b}\pm0.45$	$11.32^{c}\pm0.68$	$13.78^{d}\pm0.94$
Fat (%)	$20.08^{a}\pm1.01$	$20.22^{a}\pm1.08$	$20.53^{ab}\pm1.15$	$21.44^{b}\pm1.13$
Ash/mineral (%)	$0.28^{a}\pm0.01$	$0.28^{a}\pm0.01$	$0.32^{b}\pm0.01$	$0.34^{c}\pm0.01$
Fiber (%)	$3.81^{a}\pm0.14$	$3.45^{b}\pm0.18$	$3.49^{b}\pm0.16$	$3.05^{c}\pm0.11$
Carbohydrate (%)	$67.70^{a}\pm0.89$	$66.49^{b}\pm0.61$	$64.34^{c}\pm0.94$	$61.39^{d}\pm0.86$

*) Different letters in the same row indicate significant difference among samples ($p<0.05$)

According to our findings, cricket flour was dark brown in color and had an odor resembling fermented shrimp that could potentially lead to negative perception of the consumers towards cookies. Therefore, in our formulation, chocolate powder and vanilla extract were used to mask the flavor of cricket flour. Table 5 shows the organoleptic acceptability of cricket flour-enriched cookies. In general, the supplementation of cricket flour tended to reduce all the parameters of organoleptic acceptability, except for texture. Compared to control (cookies without cricket flour), the cookies supplemented with 5% and 10% of cricket flour were generally accepted by the panel. In contrast, the cookies supplemented with 20% of cricket flour exhibited lower organoleptic acceptability compared to control in all parameters except for texture. Such a phenomenon was due to the strong shrimp-like odor of cricket flour that did not suit the perception of the panel on cookies as a sweet food.

Table 5. Organoleptic acceptability of cricket flour (CF)-enriched cookies

Parameter	Control CF0%	Cookies CF5%	Cookies CF10%	Cookies CF20%	Commercial cookies
Aroma	$6.36^{b}\pm0.74$	$6.77^{b}\pm0.82$	$6.50^{b}\pm0.68$	$4.58^{a}\pm0.47$	$6.69^{b}\pm0.72$
Color	$7.02^{c}\pm0.81$	$6.94^{bc}\pm0.62$	$6.33^{ab}\pm0.58$	$6.07^{a}\pm0.45$	$7.38^{c}\pm0.60$
Taste	$6.58^{b}\pm0.52$	$6.47^{b}\pm0.49$	$6.38^{b}\pm0.47$	$5.36^{a}\pm0.55$	$8.02^{c}\pm0.65$
Texture	$5.98^{a}\pm0.59$	$6.13^{a}\pm0.63$	$6.44^{a}\pm0.67$	$6.24^{a}\pm0.76$	$7.80^{b}\pm0.59$
Overall	$6.69^{b}\pm0.50$	$6.61^{b}\pm0.71$	$6.55^{b}\pm0.68$	$5.52^{a}\pm0.57$	$7.77^{c}\pm0.63$

*) Different letters in the same row indicate significant difference among samples ($p<0.05$)

Enriching cookie dough with cricket flour was also shown to result in darker colored cookies. Another studies also demonstrated that the addition of cricket flour into biscuits brought specific characteristics including dark color and fishy and earthy flavor [25,26]. Apart from the natural dark color of cricket flour, it was suggested that the increase of free amino acids from cricket flour in the dough would contribute to the higher intensity of the Maillard non-enzymatic browning reaction during the cooking process [27]. Cookies of darker color also tended to obtain lower organoleptic acceptance due to the impression of overcooking. Compared to commercial cookies, cricket-flour enriched cookies exhibited a lower level of consumer acceptability. To overcome this, it would be necessary to perform further research on cookie formulation in order to improve the organoleptic acceptability of cricket flour-enriched cookies. In addition, adding spices with strong aroma, such as cinnamon or cloves, could also be considered to mask the shrimp-like odor of cricket flour. Furthermore, it would also be interesting to apply cricket flour in the production of salty food products, such as salty crackers or meatballs, since its odor would support the organoleptic profile of such food products.

4. Conclusions

The findings obtained in this study support the possibility of using cricket flour in the production of cookies for protein fortification. Substituting 5% and 10% of wheat flour with cricket flour resulted in cookies that could be accepted by consumers. The organoleptic acceptability of cricket flour-enriched cookies decreased as the amount of cricket flour used in the formulation increased. Further study is needed to improve the cookie formulation for a better consumer acceptability.

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