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FULL PAPER

Cricket as an alternative source of protein in the development of nutritious baked chips

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Abstract

The practice of eating insects, also known as entomophagy, is not common in Malaysia. Nevertheless, insects are pronounced for their high protein content, dietary fibre, unsaturated fatty acids, vitamins and minerals like calcium and iron. Next, snacks, especially potato chips available in the market are usually nutrient poor. Thus, the present study aimed to develop baked chips using cricket powder as an alternative source of protein and other minerals to enhance their nutritional values. Cricket powder was incorporated into baked chips with different formulations: control (0%), F1 (5%), F2 (10%), F3 (15%), and F4 (20%) to partially replace tapioca starch. Acceptance test using a 9-point hedonic scale was conducted to determine consumers' acceptability of the developed baked chips and F2 was reported as the most preferred formulation. There was no significant difference (p>0.05) between the control and F2 in terms of appearance, aroma, texture, taste, and overall acceptability. In terms of proximate analysis, protein, fat, and ash content of F2 cricket powder baked chips were reported as significantly higher (p<0.05) than control. Besides, F2 cricket powder baked chips can be categorized as high protein food as they contained 15.04 g of protein in 100 g of the final product. In conjunction with greater ash content, both calcium and iron content of F2 cricket powder baked chips were significantly higher (p<0.05) as compared to the control. The calcium and iron content of F2 cricket powder baked chips were reported as 2.76 mg/100 g and 5.27 mg/100 g, respectively. In conclusion, cricket powder baked chips with acceptable organoleptic properties and better nutritional profiles were successfully developed.

1. Introduction

Food insecurity is a predicament worldwide as people will soon face the challenges of getting nutritious, inexpensive, and sustainable food sources due to the fast-growing population (Shaheen *et al.*, 2017). To address this issue, one of the proposed solutions is to adopt entomophagy, which is the practice of eating insects by humans. Compared to animal farming, insects are more environmentally friendly as they require less space, and the emission of greenhouse gases (GHGs) is considerably lower (Oonincx and de Boer, 2012). For instance, insect farming can reduce the usage of land by 50% to 90% per kg of protein and the emission of GHGs is 1000 to 2700 g per kg mass gain less than the usual livestock (Payne *et al.*, 2016). Not only insects are environmentally friendly, but they also provide higher levels of nutrients and micronutrients which can satisfy one's daily dietary intake in comparison to other livestock. Insects like beetles, caterpillars, grasshoppers, and crickets are some of the popular species for consumption (Dobermann *et al.*, 2017). In conjunction with this, cricket species are more well-known as insect proteins since they are widely domesticated and farmed industrially (Kourimska and Adamkova, 2016).

Generally, crickets are renowned for their promising protein, fat, dietary fibre, and micronutrient content. First, the dietary protein content of cricket is around 66% on a dry basis, but slight variation is common depending on the cricket's species (Stone *et al.*, 2019). The level of essential and semi-essential amino acids in cricket protein is also remarkably greater than the conventional source of protein such as meat, dairy products, and legumes. Following on, lipid content occupies the second -largest portion of the nutritional composition of crickets by having approximately 21.8% of fat content. The fatty acid profile shows that C16:0 (palmitic acid) and C18:1 (oleic acid) has the highest average proportions in the category of saturated and monounsaturated fatty acids,

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respectively (Mlček *et al.*, 2018). Meanwhile, C18:2 (linoleic acid) occupies the largest quantity in the category of polyunsaturated fatty acids (Mlček *et al.*, 2018). Next, crickets contain a significant amount of crude fibre. This is because their exoskeletons are primarily made up of insoluble fibre called chitin. Insoluble fibre is associated with the effect on gut microbiota as studied by Stull *et al.* (2018). The growth and activity of beneficial intestinal bacteria can be selectively stimulated since the insoluble chitin from crickets is said to possess prebiotic properties, but this relationship is not well established yet. Apart from that, crickets also contain a reasonably high amount of minerals that are required by the human body such as calcium, iron, and potassium, suggesting that crickets can be an excellent source of food ingredients, supplements and even raw materials for medical purposes (Abulude, 2004).

Unfortunately, the barrier to entomophagy is mainly food neophobia, in which consumers show the tendency to avoid or be unwilling to try novel food products (Mancini *et al.*, 2019). Consumers are not ready to embrace the idea of entomophagy as they are disgusted by the unappealing appearance of insects. Besides, insects are often related to cognitive disgust as they are perceived as dirty and disease carriers (Deroy *et al.*, 2015). Due to such factors, the introduction of insect-related food products into the market has become a hindrance. Thus, a change in presentation is required prior to the utilization of insects as ingredients. For instance, whole crickets are transformed into flour or powder and are often utilized in the production of baked goods, pasta, meat substitutes, protein bars etc. Such an effort is to change consumers' negative perceptions of insect eating and to encourage consumption since the 'yuck' factor will be concealed and eliminated (Imathiu, 2020).

Following on, the habit of snacking is found to be more prevalent in the younger generation than the elderly, not only in Malaysia but in other countries as well (Shukri and Mohd Noor, 2017). Snacks like potato chips and crisps are often savoured due to the feeling of satiety and pleasure. Younger generations tend to emphasize taste instead of nutrition when it comes to the selection of snacks (Savige *et al.*, 2007). Unfortunately, protein, iron and calcium levels in snacks receive less attention as they are less significant compared to other nutrients like carbohydrates and fats (Gibson and Kurilich, 2013). In addition, Ochoa-Martinez *et al.* (2016) also stated that snacks are regarded as foods that provide 'empty calories' because they contribute to less than 2% of the protein requirement. This might be the reason that snacks are often regarded as nutrient-poor and energy-dense. Hence, the consumption of snacks is discouraged which in turn results in the spiking of consumers' demand for healthier snack options. In fact, modifications such as adding protein to snacks like chips, chocolate and ice creams that are traditionally treated as unhealthy are made progressively so that the products are more marketable (Chen and Eriksson, 2019). Hence, one of the objectives of this study was to formulate high-protein baked chips with improved iron and calcium content by utilizing cricket powder as a functional ingredient. The second objective was to evaluate the sensory attributes and consumer acceptability of baked chips incorporated with different concentrations of cricket powder. Lastly, the physicochemical properties of the control sample and the most preferred formulation will be examined too.

2. Materials and methods

2.1 Raw materials and ingredients

Cricket powder was supplied by Ant Futures Sdn Bhd, an edible insect company located in Ara Damansara, Selangor, Malaysia. Cornmeal, tapioca flour, xanthan gum and cheese powder were purchased from Baked with Yen Sdn Bhd, OUG, Kuala Lumpur. The other ingredients such as salt, sugar, paprika, yeast, baking soda, milk and palm oil were purchased from local hypermarkets in Malaysia. Lastly, BBQ as well as sour cream and onion flavouring powder were purchased from Hexa online store.

2.2 Preparation of cricket powder baked chips

Baked chips were prepared accordingly with five different concentrations of cricket powder, including 0% cricket powder (control), 5% cricket powder (F1), 10% cricket powder (F2), 15% cricket powder (F3) and 20% cricket powder (F4). First, cricket powder was sieved to prevent clumping. The dry ingredients such as cricket powder, cornmeal, tapioca flour, salt, sugar, paprika, yeast, baking soda and xanthan gum were weighed and mixed well in a mixing bowl. Next, liquid ingredients like milk and palm oil were added, followed by an appropriate amount of water to form a dough. Kneading was done to ensure good homogeneity and cohesiveness of the dough. Then, the dough was proofed for 15 minutes. After that, the dough was flattened and moulded into triangle shapes. They were then baked in a preheated convection oven (EKA KF723M) at 165°C for 15 mins and were cooled to room temperature before serving. The formulation was replicated for all the analyses.

2.3 Sensory evaluation

A total of 83 untrained panels (34 males and 49 females) aged between 18 to 50 years old were recruited.

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Five different formulations of cricket powder baked chips including 0%, 5%, 10%, 15% and 20% were served to the panellists in random order to avoid bias. A cup of drinking water was provided for palate cleansing between each sample. The panellists were required to score six attributes which include appearance, colour, aroma, taste, texture and overall acceptability for each sample using a 9-point hedonic scale ranging from 1 point (dislike extremely) to 9 points (like extremely). The most preferred formulation and control will be selected for further analysis.

2.4 Proximate analysis

2.4.1 Protein analysis

Protein content was determined based on the Kjeldahl method. About 2 g of homogenized baked chips were weighed into a digestion tube, followed by the addition of one tablet of Kjeltab CX and 15 mL of concentrated H_2SO_4 for sample digestion. Next, the digestion process was scheduled for 2 hours at 400°C using Kjeldatherm - Digestion Unit, SOX 416 (Gerhardht, Germany). After digestion, distillation was conducted using VAPODEST distillation system (Gerhardht, Germany). The samples were then titrated using 0.1 M hydrochloric acid until a pink colour appeared, indicating the reach of the endpoint. The percentage of nitrogen was calculated based on the formula as shown below. Lastly, the protein content (%) for each sample was obtained by multiplying the nitrogen content (%) with a conversion factor of 6.25.

$$\%\,Nitrogen = \frac{(mL\ sample - mL\ blank)(N)(14.007)(100)}{mg\ sample}$$

Where mL sample is the volume of titrant for sample (mL), mL blank is the volume of titrant for blank (mL) and N is the normality.

$$\%\,Protein = \%Nitrogen \times F$$

Where F = Conversion factor

2.4.2 Fat analysis

Fat content was determined by the Soxhlet method using a solvent extractor (EBL, Gerhardht) and Refrigerator Circulator (TLC-10A, Hi Point). First, the extraction beakers with 3 boiling stones each were preheated at 105°C for 1 hr and were cooled for another 1 hr in a desiccator. The extraction beakers together with the boiling stones were weighed to obtain M_1 reading. Next, 2 g of ground samples were weighed in a Whatman No 1 filter paper and the weight was recorded as M_0. Then, 120 mL of hexane which served as the solvent was added to each extraction beaker and the extraction process was programmed for about 3 hrs. The extraction beakers were heated again at 105°C for 1 hour and cooled. M_2 reading was obtained by measuring the cooled extraction beaker containing the residue. The percentage of fat content was calculated using the formula stated below:

$$Fat\ content\ (\%) = \frac{(M2 - M1)}{M0} \times 100$$

2.4.3 Carbohydrate analysis

Carbohydrate content was determined using the subtraction method (BeMiller, 2018) The remaining value obtained from the subtraction of protein, fat, ash and moisture content from the total weight of food (100%) was assumed to be the amount of carbohydrate.

$$Carbohydrate\ content\ (\%) = 100 - \%\ of\ protein - \%\ of\ fat - \%\ of\ ash - \%\ moisture$$

2.4.4 Ash analysis

The dry ashing method was used to determine the ash content of the samples. Crucibles containing around 8 g of samples were placed overnight in the muffle furnace at 600°C with their lids opened. The weight after ashing, the weight of the tared crucible and the original sample weight were measured, and the ash content was calculated using a dry a matter coefficient of 0.87 (Nielson, 2010).

2.4.5 Moisture content analysis

About 6 g of ground sample was spread evenly and flatly on the sample pan and it was subjected to a temperature of 200°C. A moisture analyser (MOC63u Unibloc, Shimadzu, Japan) was used to determine the moisture content of the samples.

2.5 Determination of iron content

The determination of iron content was done through an in-house method CLWI-TEC-M048 by Merieux NutriSciences based on AOAC 975.03 and AOAC 985.01.

2.6 Determination of calcium content

Samples were treated using the wet ashing method by a combination of concentrated H_2SO_4 and HNO_3 prior to calcium analysis (Nielson, 2010). After wet ashing, a flame atomic absorption spectrometer, Analyst 400 (Perkin Elmer, USA) was employed to measure the calcium content of the respective sample using a wavelength of 423 nm.

2.7 Physical analysis

Water activity (a_w), texture profile and colour of the samples were some of the physical properties being studied. First, a_w was measured using a water activity meter (AquaLab Lite, Decagon Devices Inc, USA). Next, the texture profile of the sample was analysed

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using a CT3 texture analyser (Brookfield Engineering, Middleboro, USA) with a TA10 cylinder probe. Test speed of 2.0 mm/s, 30 g of trigger load, 10000 g of load cell and compression test type were applied as the test methods. For colour analysis, a hand-held imaging spectrocolorimeter (Lovibond LC 100) was used to measure the samples in terms of their lightness (L*), redness (a*), yellowness (b*) and chroma (C*).

2.8 Statistical analysis

Statistical analysis was performed using IBM SPSS software version 23.0 (Chicago, USA). ANOVA and independent t-test were used to analyse the collected data to determine if there was any significant difference in the results at a 95% confidence interval (α = 0.05). The analysed results were expressed in mean ± standard deviation of triplicate measurements.

3. Results and discussion

3.1 Sensory evaluation of cricket powder baked chips

Based on Table 1, there was a significant difference ($p<0.05$) between control and F1 with F3 and F4 CP baked chips in terms of appearance. The visible change in the appearance of F3 and F4 CP baked chips could be influenced by the high amount of cricket powder whereas the low amount of cricket powder incorporated into control and F1 CP baked chips only lead to insignificant changes. Secondly, the colour attributes of the control and F1, F2 and F3 with F4 CP baked chips were significantly different ($p<0.05$). It was observed that the higher the concentration of cricket powder, the darker the colour of the baked chips. Iko-Ojo Dignity *et al.* (2018) also highlighted that increased cricket powder concentration will result in duller and unappealing food colour which will directly affect the overall food appearance. As a result, it was observed that the average hedonic scores for both appearance and colour decreased with the increased concentration of cricket powder incorporated. The colour attribute of F4 CP baked chips was reported to be the least favoured by having a mean rating of 4.73. They were consistently perceived as unattractive due to their dark colour appearance in which the panellists might associate the dark brown colour with burnt or overcooked. Oppositely, the control sample had the highest hedonic score of 7.25 probably due to its light orange colour.

Next, the combination of aroma and taste is an important element in the overall flavour perception. Referring to Table 1, the aroma of baked chips did not differ significantly ($p>0.05$) from each other. Generally, most of the samples were rated neither like nor dislike, except for control which was slightly preferred by the panellists. In fact, the baked chips lack a strong and distinct aroma. Unlike frying, a baking method often produces food products with lower fat content. Fat usually acts as the carrier for flavour molecules. With lower fat content, the flavour molecules lack staying power and are released quickly into the atmosphere before being served to the panellists (Figoni, 2004). Thus, the panellists may tend to allocate ‘neither like nor dislike’ choice since the aroma of baked chips cannot be perceived properly. On the other hand, a significant difference ($p<0.05$) was established between F1 CP baked chips with control and F4 CP baked chips in terms of taste. F1 CP baked chips were given the highest hedonic score of 6.54 whereas F4 with a mean rating of 5.25 was least accepted by the panellists. With a small amount of cricket powder incorporated, the taste of F1 CP baked chips are elevated as cricket powder is known to exhibit a mild earthy and nutty taste. On the contrary, F4 received the lowest score among the five formulations as the panellists consistently reported a sense of astringency and bitter aftertaste. Overall, the taste of cricket powder becomes more noticeable with its increasing concentration, thus resulting in dissatisfaction and a low hedonic score. In terms of texture, a significant difference ($p<0.05$) existed between F1 CP baked chips with the control, F3, and F4 CP baked chips. F1 CP baked chips obtained the highest rating of 6.81 among the five formulations due to their firmness and acceptable crispiness. Particularly, the control sample and F4 CP baked chips obtained the lowest ratings of 5.49 and 5.34, respectively from the panels. According to Tunick *et al.* (2013), crispness is a textural attribute that consumers crave in chips whereby it snaps easily when

Table 1. The average hedonic scores obtained from sensory evaluation for five different formulations of cricket powder baked chips.

Sensory Attributes	Formulations				
	Control (0%)	F1 (5%)	F2 (10%)	F3 (15%)	F4 (20%)
Appearance	6.87±1.63[a]	6.90±1.47[a]	6.51±1.60[ab]	6.06±1.71[b]	5.33±1.88[c]
Colour	7.25±1.37[a]	6.86±1.58[a]	6.02±1.67[b]	5.65±1.74[b]	4.73±1.94[c]
Aroma	6.04±1.75[a]	5.98±1.54[a]	5.76±1.52[a]	5.45±1.65[a]	5.36±1.77[a]
Taste	5.60±1.96[b]	6.54±1.79[a]	5.95±1.78[ab]	6.05±2.04[ab]	5.25±1.96[b]
Texture	5.49±1.82[b]	6.81±1.62[a]	6.08±1.59[ab]	5.75±1.94[b]	5.34±1.95[b]
Overall acceptability	5.93±1.74[ab]	6.59±1.83[a]	6.18±1.50[a]	6.07±1.85[a]	5.31±1.83[b]

Values are expressed in mean ± standard deviation (n = 83). Values with different superscript within the same row are significantly different ($p<0.05$).

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deformed and produces a crackly sound. However, both control and F4 CP baked chips failed to exhibit crispness. The control sample was described as too 'hard' whereas F4 CP baked chips were too crumbly. Hence, the undesirable texture of these baked chips has led to low acceptance from the panellists.

As for overall acceptability, there was a significant difference (p<0.05) between F1, F2 and F3 with F4 CP baked chips. The panellists were more inclined to F1, F2 and F3 CP baked chips as they received higher hedonic ratings. This means that the incorporation of 5%, 10% and 15% of cricket powder is acceptable for the consumers. Based on Table 1, F1 CP baked chips showed positive ratings in almost all aspects of the sensory characteristics. Nonetheless, F2 CP baked chips were chosen as the best formulation after conducting post hoc analysis as no significant difference was found between F1 and F2 CP baked chips in most of the sensory attributes, except for colour. Apart from that, it is also to optimize the usage of cricket powder so that sufficient levels of nutrients can be achieved.

3.2 Proximate analysis of control and F2 cricket powder baked chips

3.2.1 Protein content

First, the protein content of F2 CP baked chips (15.04%) was significantly (p<0.05) higher than the control (5.26%) as reflected in Table 2. The increase in protein content of F2 CP baked chips can be attributed to the excellent amino acid profile of cricket powder which consists of all the nine essential amino acids as well as promising protein digestibility (Pauter *et al.*, 2018). Studies done by Osimani *et al.* (2018) and Burt *et al.* (2019) also proved that the utilization of cricket powder in bakery products had remarkably increased their protein content as compared to the control prepared from all-purpose flour only. In addition, F2 CP baked chips can be categorized as high protein food as it contains 15.04 g of protein per 100 g of the final product. According to the Guide to Nutrition Labelling and Claims, a food product can be claimed as high protein if its protein content is double the Nutrient Reference Value (NRV) which is 5 g (Ministry of Health, 2010). In short, a high protein product must contain at least 10 g of protein. With 15.04 g of protein, F2 CP baked chips in this study have fulfilled the requirement of high protein food category.

Table 2. Proximate analysis (%) of control and F2 cricket powder baked chips.

Proximate Analysis	Control (0%)	F2 Cricket Powder
Protein	5.26±0.38[b]	15.04±0.38[a]
Fat	10.39±0.16[b]	13.57±0.07[a]
Ash	1.35±0.10[b]	2.03±0.10[a]
Carbohydrate	79.75±0.19[a]	65.34±0.26[b]
Moisture content	3.25±0.90[a]	4.02±0.17[a]

Values are expressed in mean ± standard deviation (n = 3). Values with different superscript within the same row are significantly different by Independent T-test (p<0.05).

3.2.2 Fat content

Next, the reported fat content for control and F2 CP baked chips were 10.39% and 13.57%, respectively, showing that F2 CP baked chips contained significantly (p<0.05) higher fat than the control. This is in accordance with the study done by Smarzyński *et al.* (2019) reported that the incorporation of cricket powder will certainly increase the fat content of food products as compared to the reference. Oleic acid, linoleic acid, and palmitic acid are said to be the primary contributors to the rise in fat content of cricket food products (Kim *et al.*, 2016).

3.2.3 Carbohydrate content

On the other hand, there was a significant (p<0.05) reduction in carbohydrate content for F2 CP baked chips (65.34%) in comparison to the control sample (79.75%). The decrease in carbohydrate content is related to the increase in protein, fat and ash content of F2 CP baked chips (Iko-Ojo Dignity *et al.*, 2018; Pauter *et al.*, 2018).

3.2.4 Moisture content

In terms of moisture content, no significant difference (p>0.05) was found between control and F2 CP baked chips. Nevertheless, the moisture content of F2 CP baked chips was 4.02%, which was slightly higher than the control of 3.25%. This is due to the moderate amount of dietary fibre from cricket powder and cornmeal in the dough mixture (Stull *et al.*, 2018). Dietary fibre has a known function of retaining water in food, thus contributing to an increase in moisture content (Varastegani *et al.*, 2014).

3.3 Ash, iron and calcium content

Ash refers to the remaining inorganic residues like minerals after complete oxidation and combustion. Referring to Table 2, the ash content in F2 CP baked chips (2.03%) was greater than the control (1.35%), which indicates the presence of a higher amount of minerals (Shantibala *et al.*, 2014). This was aligned with the iron and calcium content of F2 CP baked chips as they were significantly higher (p<0.05) than the control sample (Table 3). The iron and calcium content of F2 CP baked chips was almost 2 times and 1.4 times greater than the control, respectively. In fact, cricket powder is endorsed as a good source of micronutrients since it is rich in different types of minerals such as calcium, potassium, zinc and iron (Duda *et al.*, 2019). The

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nutritional value of baked chips incorporated with cricket powder is certainly enhanced as the chips available in the market usually lack iron and calcium. Such minerals may be neglected since it is not an important element to be considered in the production of snack foods.

Table 3. Iron and calcium content (mg/100 g) of control and F2 cricket powder baked chips.

Mineral Content (mg/100 g)	Control (0%)	F2 Cricket Powder Baked Chips (10%)
Iron	2.77±0.09[b]	5.27±0.09[a]
Calcium	1.98±0.05[b]	2.76±0.21[a]

Values are expressed in mean ± standard deviation (n = 3). Values with different superscript within the same row are significantly different by Independent T-test (p<0.05).

3.4 Physical analysis

3.4.1 Water activity (a_w)

Referring to Table 4, the control and F2 CP baked chips exhibited similar a_w of 0.34 and 0.35, respectively. They are classified as low moisture food and shelf-stable because microorganisms require a minimum a_w of 0.60 to thrive and proliferate (Ijabadeniyi and Pillay, 2017). Specifically, the low a_w of F2 CP baked chips may be due to the a_w of cricket powder itself. Like other meat, insects are high in moisture too. For this reason, crickets are usually roasted before milling for moisture removal so that the growth of Enterobacteriaceae, fungi and yeast can be eliminated (Klunder *et al.*, 2012). As a result, cricket powder will possess low a_w which in turn affects the a_w of its final product.

Table 4. Water activity (aw) of control and F2 CP baked chips.

Sample	Water activity (a_w)
Control	0.34±0.00[a]
F2 CP baked chips	0.35±0.06[a]

Values are expressed in mean ± standard deviation (n = 3). Values with different superscript within the same row are significantly different by Independent T-test (p<0.05).

3.4.2 Texture profile analysis

Based on Table 5, a significant difference (p<0.05) existed in terms of hardness value whereby the force required to break the control sample (1284 g) was higher than F2 CP baked chips (530 g). A study conducted by Kowalczewski *et al.* (2019) validated that the hardness of food products decreased with the introduction of cricket powder. Cricket powder is suggested to impart emulsifying properties which subsequently lead to the softening of baked products. Hence, F2 CP baked chips are softer. Besides, moisture content can affect the textural properties of baked chips. In this study, control with low moisture content was found to be harder than F2 CP baked chips with higher moisture content. This is aligned with the statement elucidating that food products with lower moisture content usually exhibit harder textures (Chaiyakul *et al.*, 2008). Following on, cohesiveness is the degree of food structure deformation prior to breaking, crumbling or cracking (Aguirre *et al.*, 2018). A negative correlation between hardness and cohesiveness was observed. F2 CP baked chips were also significantly (p<0.05) more cohesive than the control. This might be due to the cohesion property of proteins from cricket powder that strengthens the internal bonds in the food matrix (Jeewanthi *et al.*, 2015).

Table 5. Hardness (g) and cohesiveness of control and F2 CP baked chips.

Sample	Hardness (g)	Cohesiveness
Control	1284±257.62[a]	0.01±0.00[b]
F2 CP baked chips	530±54.01[b]	0.18±0.10[a]

Values are expressed in mean ± standard deviation (n = 3). Values with different superscript within the same row are significantly different by Independent T-test (p<0.05).

3.4.3 Colour

Overall, the L*, a*, b* and C* colour properties of control and F2 CP baked chips were significantly (p<0.05) different from each other as reflected in Table 6. From Figure 1, darker brown colour was observed in F2 CP baked chips and was contributed by non-enzymatic browning known as the Maillard reaction (Purlis and Salvadori, 2009). The degree of brown colour change is dependent on the amount of amino acids and reducing sugars. With the use of cricket powder, the protein content of F2 CP baked chips increases and the formation of Maillard reaction products, predominantly melanoidins are expected to be easier (Pauter *et al.*, 2018). Melanoidins are responsible for the browning of baked chips which consequently reduces the lightness of F2 CP baked chips. On contrary, control without cricket powder appears lighter (higher L* value) since its protein content is lower and the Maillard reaction only occurs to a minimal extent. Following on, a* represents the red/green colour coordinate whereas the b* parameter indicates the degree of blue or yellow colour of an item. The a* and b* values for F2 CP baked chips were

Table 5. Hardness (g) and cohesiveness of control and F2 CP baked chips.

Sample	L*	a*	b*	b*	c*
Control	59.2±0.50[a]	21.7±0.50[a]	44.8±0.90[a]	49.8±0.40[a]	49.8±0.40[a]
F2 CP baked chips	48.9±0.20[b]	18.1±0.30[b]	36.8±0.10[b]	41.0±1.00[b]	41.0±1.00[b]

Values are expressed in mean ± standard deviation (n = 3). Values with different superscript within the same row are significantly different by Independent T-test (p<0.05).

comparable to the results reported by Pauter *et al.* (2018) stating that the colour balance of cricket powder products had shifted towards green and blue, respectively. Lastly, C* refers to the dullness and vividness of a colour, also known as chroma. The greater C* value showed that the control exhibited a brighter colour while F2 CP baked chips were duller as reflected in its smaller C* value.

Figure 1. The colour of (a) control and (b) F2 CP baked chips.

4. Conclusion

All in all, the objectives of this study were achieved. The development of high protein cricket powder baked chips with improved iron and calcium content was considered a success. F2 CP baked chips showed a significantly ($p<0.05$) higher amount of protein, iron and calcium when compared to the control. Additionally, F2 CP baked chips can be claimed as high protein food in accordance with Malaysia's health authorities. Next, sensory evaluation of baked chips with five different concentrations of cricket powder brought to light that the incorporation of 10% cricket powder was optimum in terms of organoleptic properties. Since then, the amount of cricket powder and its usage as a food ingredient to improve the nutritional content of a product was enlightened. The results obtained from this study will be beneficial for the future development of cricket-related food products to support food sustainability.

Conflict of interest

The authors declare no conflict of interest.

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