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Amino acid composition and chemical properties of protein noodles incorporated with cricket (*Gryllus bimaculatus* De Geer) powder

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Abstract

Crickets (*Gryllus bimaculatus* De Geer) are considered a primary meat-alternative protein source. The insects comprise of 58 - 63% high-quality protein rich in essential amino acids. Nowadays, noodles are regularly consumed. Cricket powder-based protein noodles (PNCP) could be a choice for individuals with gluten allergies. In the present work, PNCP 0%, PNCP 15%, and PNCP 30% were assessed. PNCP 30% yielded the optimal nutritional quality in terms of moisture, ash, crude protein, crude fat, and crude fibre contents. It also contained the highest levels of 18 amino acids. Results also revealed that the noodles incorporated with cricket powder had double aspartic acid content, and increased proline content (3 - 7%) compared to control samples. Statistical analysis demonstrated a direct correlation between increased nutritional quality and the cricket powder amount added. Nevertheless, increasing cricket powder amount affected the colour of the resultant noodles. PNCP 30% yielded the darkest hue amongst the samples with an L* value of 38.21 ± 1.93%. Conversely, PNCP 0% and 15% samples yielded 56.18 ± 0.75 and 45.06 ± 1.66% L* values, respectively. Texture profile analysis also revealed the effects on the tensile strength values of enhancing the cricket powder content. Panellists scored the PNCP samples on a 9-point hedonic scale in a five-dimensional sensory evaluation. PNCP 15% recorded the ideal combination of palatability, appearance, and characteristics. Overall, the present work demonstrated that whilst utilising cricket powder as the alternative protein source in noodles is feasible, an accompanying sensory evaluation is critical to ensure that its incorporation does not compromise consumer acceptance of the final product.

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Introduction

Food allergy is an aberrant immunological response to food antigens (Onyimba *et al*., 2021). For instance, coeliac disease arises from allergic reactions towards gluten, a naturally occurring protein in grains, including wheat, rye, and barley (Lebwohl *et al*., 2018; Anil *et al*., 2021). As awareness about the disease increases, the food manufacturing industry also continuously strives to provide gluten-free products, especially for patients who have a strict gluten-free diet as an effective treatment (Capriles and Areas, 2014). Various gluten-free breads suitable for individuals suffering from coeliac disease are currently available, such as brown rice flour (Luo *et al*., 2021), buckwheat and chia (Coronel *et al*., 2021), and sourdough (Nissen *et al*., 2020).

However, the absence of gluten reduces the carbon dioxide retention rate, a critical leavening element of the bread-making process. Gluten-free bread is often dense, hence considered less desirable than standard bread. Therefore, some researchers recommended people living with coeliac disease to enhance their noodle intake instead. Noodles are convenient, palatable, and have long shelf life due to their low water activity (a_w) (Hou *et al*., 2017; Chen *et al*., 2020).

Several noodle-based products, including instant fried noodles with oat bran (Reungmaneepaitoon *et al*., 2006), fresh wet noodles

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(Xing *et al*., 2021), and dry Chinese noodles with sweet potato flour (Zhang *et al*., 2010) have emerged in the market over the years. Although lack of protein quantity, noodle products typically provide carbohydrates as a primary nutrition. Therefore, protein noodles offering carbohydrates and protein should appeal to more consumers.

At least 2,000 edible insect species are found worldwide. Humans have been consuming crickets (*Gryllus bimaculatus* De Geer) for a long time (Jongema, 2015; Ghosh *et al*., 2017). Crickets are also one of the top five commercial insects in South Korea (Ghosh *et al*., 2017). Furthermore, Musundire *et al*. (2014) reported that ground crickets are consumed in south-eastern Zimbabwe as a dietary supplement due to their fibre, flavonoid, and protein-rich nature. Ghosh *et al*. (2017) recorded that crickets comprise of approximately 53.2 to 58.3% protein, while Stone *et al*. (2019) stated that cricket powder is 66% protein (dry weight), 5% ash, and 16.1% lipid. Of the total lipid content, 77.51% is attributable to unsaturated fatty acids, such as linoleic, oleic, and linolenic acids (Womeni *et al*., 2009).

The gluten-free sourdough bread developed by Nissen *et al*. (2020) was added with cricket flour, resulting in high nutritional value protein and antioxidant-rich bread. Consequently, edible insects, including cricket, could be an alternative protein source in gluten-free foods (Musundire *et al*., 2014; Ghosh *et al*., 2017; Stone *et al*., 2019). Cricket powder could also potentially be a key ingredient in protein noodles.

Based on the Recommended Dietary Allowance (RDA) guideline (Harvard Health Publishing, 2023), humans require 0.8 g of protein per kg of body weight. Protein intake is crucial to strengthen and repair damaged tissue cells. Nevertheless, some individuals suffer from protein allergies. The issue might be solved with alternative protein sources, such as edible insects.

The present work thus aimed to examine the amino acid profiles and chemical properties of protein noodles incorporated with cricket powder (PNCP). A five-dimensional sensory evaluation was also performed, which assessed consumers' perceptions of the product. The findings could contribute valuable knowledge about alternative protein sources and its potential utilisation in food products suitable for consumption by people with and without coeliac disease.

Materials and methods

Sample preparation

Cricket powder preparation

The cricket powder was produced from live crickets received from the Siamtech Farm, Khon Kean Province, Thailand. The facility specialises in cricket farming. First, the crickets were washed thoroughly before being dried at 60°C for 6 h in a hot air oven (Memmert, Germany). The dried crickets were blended and sifted through a 100-count mesh sieve. The final product, which was a fine powder, had an a_w value of 0.41. The powder was kept at -18°C until subsequent analyses.

Protein noodle preparation

Three levels of PNCP were prepared each containing different cricket powder contents: 0% (PNCP 0%), 15% (PNCP 15%), and 30% (PNCP 30%) (see Figure 1). A blend of rice and tapioca flour was the noodle base. A measured amount of the rice and tapioca flour blend was combined with hot water to form a dough in a standard tabletop mixer (Kitchen Aid). The cricket powder was introduced during the mixing stage.

After being steamed for 15 min at 100°C, the cooked dough was returned to the stand mixer to be thoroughly kneaded to the desired texture. Subsequently, the dough was cut into small pieces, and repeatedly passed through a pasta roller to obtain noodle samples of a standardised thickness (No. 4). The noodle sheets were cut into strips, and portioned before being oven-dried (Memmert, Germany) at 60°C for 3 h.

Proximate composition analysis

The chemical properties, including moisture, ash, crude protein, fat, fibre, and energy of the PNCP samples were analysed following AOAC (2000). The moisture contents were determined post-desiccation in a hot air oven at 100 - 105°C for 4 h (AOAC, 2000), while ash contents were determined by dry combustion (Choo and Aziz, 2010). Protein contents were determined by Kjeldahl method (%N × 5.7; AOAC, 2000), and fat contents were determined by petroleum ether extraction method (Reungmaneepaitoon *et al*., 2006). Each noodle type was analysed in triplicates, and results were expressed in dry weight basis.

PNCP 0% **PNCP 15%** **PNCP 30%**

Figure 1. Protein noodles incorporated with different amounts of cricket powder. PNCP 0%: protein noodles incorporated with 0% cricket powder; PNCP 15%: protein noodles incorporated with 15% cricket powder; PNCP 30%: protein noodles incorporated with 30% cricket powder.

Amino acid analysis

The amino acid analysis utilised the HP 1260 High Performance Liquid Chromatography (HPLC) platform (Agilent Technology, Germany) following AOAC (1990). The levels of 18 amino acids within each PNCP sample were measured in the analysis. The ground noodle samples were hydrolysed in 6 N hydrochloric acid (HCL) at 110°C for 24 h under nitrogenous atmospheric conditions. The PNCP samples were then concentrated on a rota-evaporator, and reconstituted with a sample dilution buffer (0.12 N, pH 2.20).

The standardised operating parameters applied in the present work adhered to the protocol suggested by Ghosh *et al.* (2017). The Princeton SPHER C30; 250 mm ID, 4.6 mm column; a physiological application; fluorescence detector (FLD) Ex: 340, Em: 450; ninhydrin reaction detection principle; 65 min run time; 0.7 mL/min flow rate; 35 µL injection volume; and nitrogen gas (N_2) were employed. The results were calculated based on the WHO/FAO/UNU guidelines (WHO, 2007).

Colour analysis

A Miniscan EZ [Hunter Associates Laboratory Inc., United States of America (USA)] was utilised to determine the colour of the PNCP samples. The evaluation was based on the CIELAB 1976 L*, a*, b* colour scales. The L* value indicates lightness or darkness within a 0 to 100 range, where 0 = black and 100 = white. Similarly, the a* value indicates redness and greenness (-a* = greenness, +a*= redness), whilst b* value indicates yellowness and blueness (-b* = blueness, +b* = yellowness). PNCP samples were subjected to surface measurements from three positions. Subsequently, they were ranked on the colour scales based on the averaged L*, a*, and b* values.

Texture profile analysis

The textural characteristics of cooked PNCP samples were measured in tensile strength assessments. The texture analyser model $TA\text{-}XT_{2i}$ (Stable Micro System Ltd., Vienna Court, Lammas Rd., Godalming, Surrey, English) platform, spaghetti tensile grips (A/SPR), and 100 mm cylinder probe were employed in the analysis. Reungmaneepaitoon *et al.* (2006) and Purwandari *et al.* (2014) outlined the detailed evaluation procedures.

The cooked PNCP samples were prepared and assessed individually. The Texture Expert Software was utilised to determine the texture profile of the samples. The results were expressed as mean ± standard deviation. The analysis was performed in ten replications.

Sensory analysis

A 9-point hedonic scale (1 = dislike extremely and 9 = like extremely) was employed as an appraisal tool in the sensory evaluation. Thirty panellists (*n* = 30), comprising untrained students and staff of Science Park, Khon Kean University, Thailand, were employed for the assessment. The PNCP samples were boiled in drinking water for 5 min before being stored at room temperature for 1.5 h in covered plastic food containers before the evaluation.

During the sensory evaluation, each panellist was asked to consume the noodle samples to determine the consumer acceptance. The panellists assigned individual scores to the samples using the hedonic scale. The samples were assessed based on colour, smell, taste, texture, and overall acceptability. Subsequently, the scores were compiled before being analysed statistically.

Statistical analysis

All data collected were analysed using SPSS (Illinois, U.S.A) *via* the One-way analyses of variance (ANOVA). The results obtained were then presented as mean ± standard deviation. A 0.95 confidence level ($p < 0.05$) was considered as significantly different. Subsequently, Duncan's multiple range tests were applied post-analysis to indicate the mean differences. Proximate and amino acid analyses were conducted in three replicates ($n = 3$), colour analysis in five replicates ($n = 5$), texture analysis in ten replicates ($n = 10$), and sensory analysis in 30 replicates (panellists) ($n = 30$).

Results and discussion

Proximate analysis

Table 1 summarises the results of the proximate composition analysis and properties of the pure cricket powder produced in the present work. The pure cricket powder recorded high crude protein, 63.14 ± 0.19%, with 5.29 ± 0.03% moisture, 11.75 ± 0.32% ash, 18.07 ± 0.28% crude fat, and 9.48 ± 0.36% crude fibre. Ghosh *et al*. (2017) reported similar protein contents in crickets (58.32 ± 0.33%), which were the highest by weight among five edible commercial insects in South Korea.

The cricket powder offered 5.61 ± 0.02 kcal of energy per gram. Consequently, increasing the cricket powder percentage incorporation in protein noodles could alter the proximate composition. PNCP 0% recorded the highest moisture content (11.55 ± 0.02%), followed by the PNCP 15% (7.18 ± 0.04%) and PNCP 30% (6.93 ± 0.10%). Conversely, the PNCP 30% recorded the highest ash, crude protein, crude fat, crude fibre, and energy, while PNCP 0% the lowest.

Results also revealed that increasing the amount of incorporated cricket powder concordantly increased the levels of the chemical properties and crude protein content of the PNCP samples. Nevertheless, the samples contained reduced moisture content. PNCP 15% and 30% yielded 16.19 ± 0.23 and 23.03 ± 0.26% crude protein content, respectively. Conversely, PNCP 0% was only composed of 6.33 ± 0.07% crude protein.

The amounts of ash, crude fat, crude fibre, and energy recorded identical trends to crude protein. Nevertheless, some food processing techniques, such as frying and fermentation, reportedly reduced the nutritional values of flour, soy flour, and maize flour (Lakra and Sehgal, 2009). Therefore, cricket preparation should include suitable processes to maintain their nutritional quality.

The cricket powder produced in the present work documented high protein percentage (63.14%). The data supported the report by FAO (2012), which stated that protein from insects could be an emerging opportunity as an alternative protein source, especially in developing countries. Nonetheless, the potentials and effects of digesting and absorbing insect proteins on humans require further investigation.

Table 1. Proximate compositions of protein noodles incorporated with different amounts of cricket powder.

Sample	**Proximate Composition (% by wet basis)**					
	Moisture	**Ash**	**Crude protein**	**Crude fat**	**Crude fibre**	**Energy (Kcal/g)**
Cricket powder	5.29 ± 0.03	11.75 ± 0.32	63.14 ± 0.19	18.07 ± 0.28	9.48 ± 0.36	5.61 ± 0.02
PNCP 0%	11.55 ± 0.02^a	0.20 ± 0.00^c	6.33 ± 0.07^c	1.03 ± 0.04^c	0.90 ± 0.03^c	3.69 ± 0.01^c
PNCP 15%	7.18 ± 0.04^b	0.68 ± 0.02^b	16.19 ± 0.23^b	2.31 ± 0.05^b	2.63 ± 0.01^b	4.20 ± 0.02^b
PNCP 30%	6.93 ± 0.10^c	3.37 ± 0.25^a	23.03 ± 0.26^a	5.36 ± 0.21^a	3.67 ± 0.15^a	4.43 ± 0.03^a

Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p < 0.05$). PNCP 0%: protein noodles incorporated with 0% cricket powder; PNCP 15%: protein noodles incorporated with 15% cricket powder; PNCP 30%: protein noodles incorporated with 30% cricket powder.

Amino acid analysis

The profiles of 18 amino acids (aspartic and glutamic acids, serine, threonine, histidine, glycine, alanine, arginine, tyrosine, valine, methionine, cystine, isoleucine, phenylalanine, tryptophan, leucine, lysine, and proline) in 100 g of noodle samples produced in the present work are shown in Figure 2. Results indicated that increasing the cricket powder percentages affected the amino acid quantities.

PNCP 30% contained the highest amounts of amino acids, particularly aspartic acid, which demonstrated 100% improvement with the addition of cricket powder. Glutamic acid levels also increased significantly from 58.14 to 65.44%. The drastic changes might have been due to the naturally remarkably low amounts of amino acids in wheat products.

The lysine level, an amino acid more commonly found in staple food including wheat, rice, and cassava (Macrae *et al*., 1993), significantly increased by 387.47 and 391.90 mg/100 g in PNCP 15% and 30%, respectively. The proline content in PNCP samples incorporated with cricket powder also increased from 3 to 7% compared to PNCP 0%.

Arginine is another essential amino acid supplemented by cricket powder. The level of arginine in the noodle samples increased by 51.91 and 63.25% in PNCP 15% and 30%, respectively. Consequently, the PNCP products prepared in the present work could serve as an exceptionally beneficial alternative protein source for children as they require higher levels of arginine-derived diet to support their rapid growth (Ghosh *et al*., 2017).

Generally, the profile analysis demonstrated a positive correlation between the incorporation of cricket powder and improved amino acid levels. Nevertheless, an outlier was detected in tryptophan. The amino acid level remained within the low range (85.83 - 200.04 mg/100 g) regardless of the cricket powder content.

Adebowale *et al*. (2005) reported that male crickets lacked tryptophan. Similarly, Stone *et al*. (2019) recorded that mealworm was also tryptophan-deficient. Meanwhile, Patrignani *et al.* (2020) suggested employing yeast inoculation to increase amino acid contents in cricket powder dough. The present work also found that cricket powder-based food products could improve and provide high-quality amino acids.

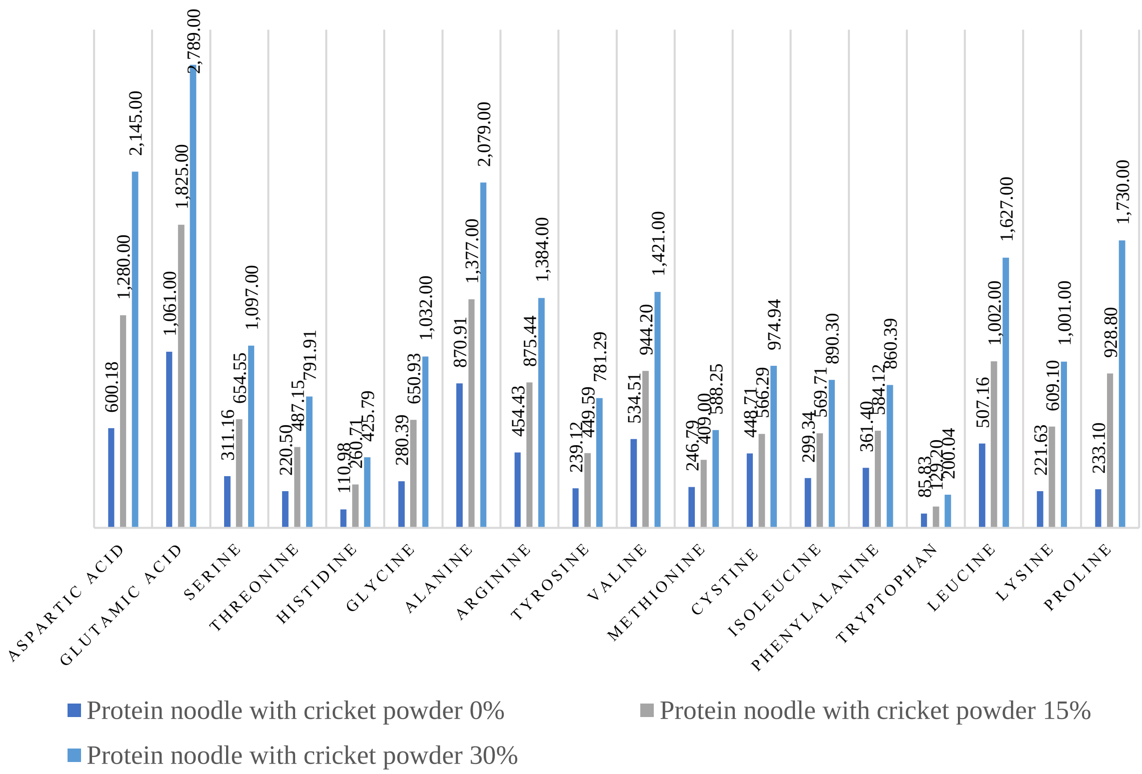


Figure 2. Amino acid profile (mg/100 g) of protein noodles incorporated with different amounts of cricket powder.

Zhang *et al*. (2010) stated that four Chinese wheat flour noodles, Yannong, Zimai, Weimai, and Wennong recorded protein contents between 11.87 and 13.90%. The number of essential amino acids in the Chinese wheat flour noodles was lower than those manufactured with cricket powder. The incorporation of cricket powder also significantly improved the levels of a majority of the 18 essential amino acids evaluated in the present work. The results proved that cricket powder could be a source of high-quality protein.

Colour analysis

The colour analysis of PNCP samples are listed in Table 2. The CIELAB L*, a*, and b* colour scales guided scoring on the lightness or darkness, redness or greenness, and yellowness or blueness of the samples, respectively. The highest L* value was recorded by PNCP 0% (56.18 ± 0.75), followed by PNCP 15% (45.06 ± 1.66), and PNCP 30% (38.21 ± 1.93). Consequently, PNCP 0% was the lightest in terms of the colour of the noodle variants.

The b* value recorded by PNCP 0% (21.62 ± 0.92) was the highest, while the lowest was recorded by PNCP 30% (15.98 ± 0.89). The results indicated that PNCP 0% was the most intensely yellow noodle sample. The a* values of the three noodle variants were not significantly different ($p > 0.05$), which were within the 5.50 - 5.89 range.

Based on the data, increasing the amount of cricket powder incorporation simultaneously decreased the lightness and yellowness intensity of the samples as they gained a darker hue. For instance, PNCP 30% contained the highest cricket powder content and the lowest L* and b* values. Nevertheless, some studies suggested that it is possible to improve L* values by substituting the noodle base with other non-wheat flours from rye, barley, or sweet potato resources (Kruger *et al*., 1998; Pangloli *et al*., 2000; Zhang *et al*., 2010).

Table 2. Colour measurement of protein noodles incorporated with different amounts of cricket powder.

Sample	L*	a*	b*
PNCP 0%	56.18 ± 0.75[a]	5.89 ± 0.69[a]	21.62 ± 0.92[a]
PNCP 15%	45.06 ± 1.66[b]	5.59 ± 0.99[a]	17.04 ± 0.27[b]
PNCP 30%	38.21 ± 1.93[c]	5.50 ± 0.70[a]	15.98 ± 0.89[c]

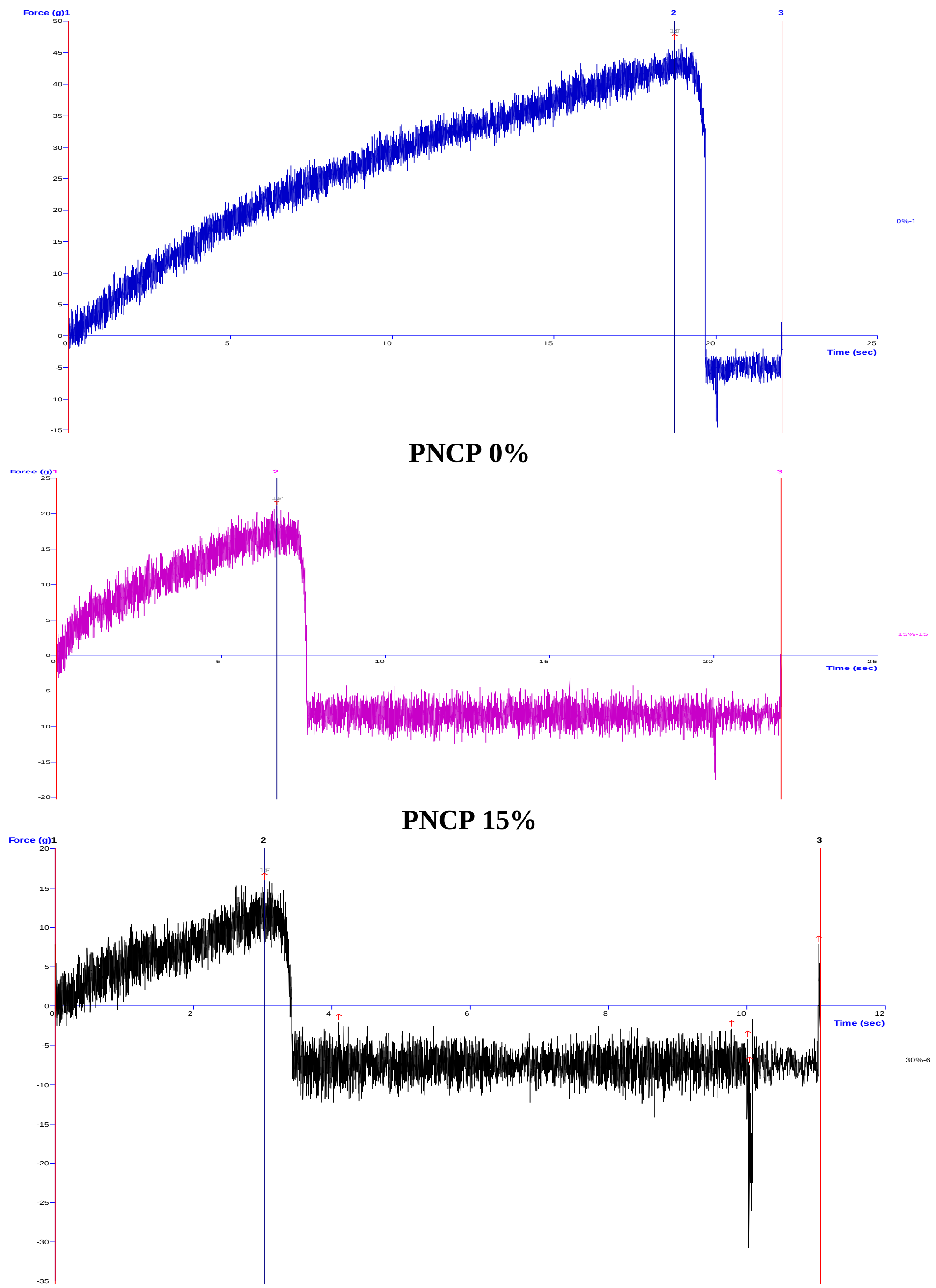
Values are mean ± standard deviation. Means followed by different lowercase superscripts in the same column are significantly different ($p < 0.05$). PNCP 0%: protein noodles incorporated with 0% cricket powder; PNCP 15%: protein noodles incorporated with 15% cricket powder; PNCP 30%: protein noodles incorporated with 30% cricket powder. L: lightness (0 - 100); a*: -a* = greenness, +a*= redness; b*: -b* = blueness, +b* = yellowness.

Texture analysis

Figure 3 illustrates the texture analysis results of the three cooked PNCP samples produced in the present work. The assay determined the textural properties of foods with a human chewing simulator. PNCP 0%, 15%, and 30% noodles recorded tensile strengths (maximum force) of 27.79 ± 1.89, 19.62 ± 2.88, and 17.50 ± 1.09, respectively. The decreasing trend of tensile strength required with increasing cricket powder content indicated that a human could chew and cut PNCP 30% in 20 s with more ease than the other two samples.

Although PNCP 30% was highly nutritious, the noodle did not conform to good noodle physical attributes. Based on the results, the protein noodle incorporated with cricket powder was less chewy than the control samples, as evidenced by the low tensile strength of PNCP 30%. Consequently, the higher percentage of cricket powder could affect the eating quality of the cooked noodle. Nonetheless, the chewiness could also be attributed to base flour blend composition. Reungmaneepaitoon *et al*. (2006) suggested that noodles with high starch paste viscosity were optimal for noodle quality and consumption.

Hera *et al*. (2013) examined the effects of rice flour on gluten-free bread, and affirmed that the ratio of rice to other flours vastly influenced the adhesiveness quality of the final product. The incorporation of non-wheat flours, including sweet potato flour, could also reduce the hardness of cooked noodles by reducing their overall gluten content (Zhang *et al*., 2010). Similarly, incorporating larger amounts of cricket powder proportionally reduced the tensile strength of the noodle samples, as demonstrated in the present work.



PNCP 0%

PNCP 15%

PNCP 30%

Figure 3. Texture profile analysis of protein noodles incorporated with different amounts of cricket powder.

Sensory analysis

The sensory evaluation conducted in the present wok involved five dimensions namely colour, smell, taste, texture, and overall acceptability. Thirty panellists ranked the PNCP samples produced in the present work on a 9-point hedonic scale (Figure 4). Results indicated that most of the panellists preferred the colour of either PNCP 0% or 15% (7.10 ± 1.89 and 7.43 ± 1.25) over PNCP 30%.

Incorporating cricket powder in large amounts significantly altered the shade of the resultant cooked noodles. Zhang *et al*. (2010) suggested incorporating sweet potato flour to overcome the issue. Similar approach has been employed to improve traditional Chinese noodles, where the colour score of the product was reduced.

In the present work, the dark PNCP 30% recorded the lowest colour score (5.23 ± 1.25). The amount of cricket powder in the sample also affected its smell, taste, texture, and overall acceptability. Consequently, PNCP 30% received the lowest scores among all treatments. Conversely, PNCP 0% scored the highest for smell (6.70 ± 0.89), followed by PNCP 15% (6.20 ± 1.05).

PNCP 15% was the preferred choice amongst the panellists, achieving the highest scores for taste (7.26 ± 0.95), texture, and overall acceptability (7.66 ± 0.95). Results revealed that despite the nutritional advantages offered by PNCP 30%, consumers were not satisfied with its sensory characteristics. Conclusively, incorporating 15% cricket powder into protein noodles could be suitable, as it preserved the palatability of the end product. A similar sensory evaluation conducted by Reungmaneepaitoon *et al.* (2006) concurred with this conclusion. The study reported that panellists preferred the middle content of 10% oat bran concentrate to replace wheat flour, even though 15% content yielded higher amount of β-glucan.

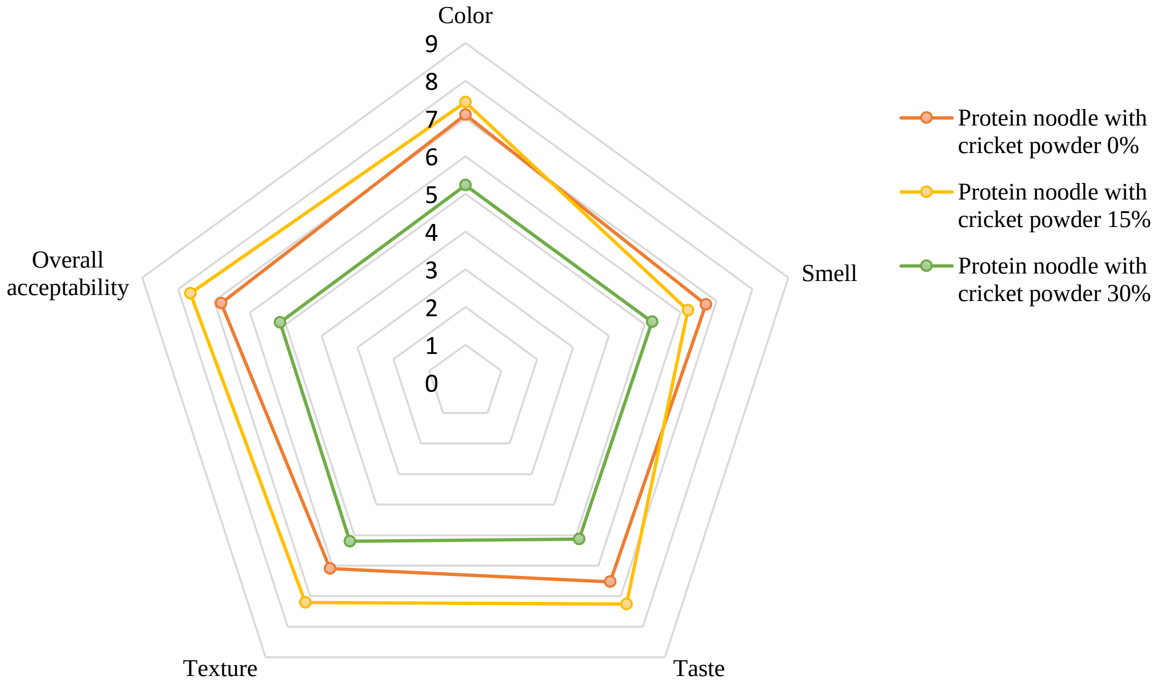


Figure 4. Sensory analysis of protein noodles incorporated with different amounts of cricket powder. Panellists evaluated each characteristic of the samples using 9-point hedonic scale (n = 30; mean ± SD).

Conclusion

Edible insects could become crucial sources of protein due to their higher protein content than other non-meat protein resources, including yellow peas, beans, and legumes (Stone *et al.*, 2019). The present work determined the amino acid composition and chemical properties of protein noodles incorporated with pulverised cricket powder. The noodle samples evaluated were PNCP 0%, 15%, and 30%, which were incorporated with different weights of cricket powder. The proximate composition analysis revealed that PNCP 30% contained the highest levels of crude protein, fat, and fibre. Similarly, the amino acid analysis results supported the high-quality nature of cricket powder protein. The incorporation of cricket powder significantly improved amino acid compositions in the noodle samples. Nevertheless, increasing cricket powder amount led to a decrease in tensile strength; softer noodles were obtained. PNCP 30% recorded the darkest colour, a trait considered undesirable by panellists in the sensory evaluation performed. The panellists indicated that PNCP 15% was their preferred choice. The sample recorded the highest scores in taste, texture, and overall acceptability. Based on the results, 15% cricket powder was the most suitable amount in noodles, and could be considered for commercial protein noodles. This noodle sample also demonstrated the ideal balance of added nutritional contents and consumer acceptance. Nevertheless, the effects of incorporating cricket powder on the rheological, structural, and nutritional aspects in terms of digestibility of insect protein products require further studies.

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