Product development of grasshopper *pempek* as additional food for pregnant woman

Sessy Paramita Lirizka[1]*, Faisal Anwar[2], Eny Palupi[2]
[1] Nutrition Program, Faculty of Public Health, Universitas Sriwijaya, Indralaya, Indonesia
[2] Department of Community Nutrition, Faculty of Human Ecology, IPB University, Bogor, Indonesia

Email : sessy_paramita_lirizka@fkm.unsri.ac.id

ABSTRACT

The demand for nutritious protein sources for pregnant women is growing, particularly to address malnutrition in Indonesia. Wood grasshoppers (*Valanga nigricornis*) offer an environmentally sustainable, nutrient-dense protein alternative. This study developed *pempek* from wood grasshoppers as a food product for pregnant women. A laboratory experiment used a completely randomized design with three formulations varying wood grasshopper and tapioca flour proportions: F1 (75:25 grasshopper:tapioca), F2 (50:50), and F3 (25:75). Organoleptic tests showed greater preference for F1 and F2 over F3; F2 was selected as the best due to its higher protein and iron content. Wood grasshopper *pempek* (F2) shows potential as a nutritious alternative to improve nutritional adequacy for pregnant women, particularly in meeting protein and iron needs. Future research should examine nutritional enhancement via amino acid modification, such as addition of methionine-rich foods.

Keywords: edible insects, product development, pregnant women, organoleptic test, wood grasshopper *pempek*

INTRODUCTION

The rapid growth of the global population has increased demand for protein-rich foods (Ruiz et al., 2025). A major challenge in achieving sustainable food security is supplying sufficient protein from conventional animal sources such as beef, poultry, and fish (Lange & Nakamura, 2021). Rising food demand has driven up prices, with projections of an average increase exceeding 25% in coming years (Aigbedion-Atalor et al., 2024). The Food and Agriculture Organization attributes this imbalance to discrepancies between food production and population growth. In response, insects have emerged as a promising protein source worldwide (Amoah et al., 2023). More than 1900 insect species are edible and consumed in many developing countries. Insect farming is environmentally sustainable, with lower greenhouse gas emissions and better feed conversion efficiency than traditional livestock systems (Tang et al., 2019).

Globally, more than 30% of the population consumes insects regularly, particularly in cultures where the practice is entrenched (Lirizka et al., 2021; van Huis, 2020). Edible insects provide high nutritional value, with protein content comparable to that of meat and eggs (Lange & Nakamura, 2021). They are also rich in essential micronutrients, including iron, zinc, magnesium, amino acids, and polyunsaturated fatty acids, which support maternal health during pregnancy (Zerfu & Mekuria, 2019). Pregnancy increases energy and nutrient needs to support fetal development. The 2019 Recommended Dietary Allowances specify an additional 300 kcal and 30 g of protein daily for pregnant women, along with adequate fats, vitamins, and minerals. Nutritional deficiencies during pregnancy can cause anemia, obstetric hemorrhage, and higher maternal mortality. Inadequate macronutrient and micronutrient intake can also impair fetal growth, resulting in low birth weight, stunting, and increased risk of degenerative diseases later in life (Hendrixson et al., 2025).

Although the Indonesian government has implemented supplementary feeding programs for pregnant women, these efforts have had limited success in reducing maternal undernutrition. The 2018 Basic Health Research survey reported chronic energy deficiency in 17.3% of pregnant women and anemia in nearly half (Kementerian Kesehatan Republik Indonesia, 2018). These conditions arise primarily from inadequate dietary intake and limited access to diverse, nutrient-dense foods (Brabin et al., 2001). Accordingly, researchers have focused on locally sourced food formulations to address the nutritional needs of this population (Lestari et al., 2025).

As a tropical nation with rich biodiversity, Indonesia has substantial potential for insect-based food development. The wood grasshopper (*Valanga nigricornis*), known locally as the Javanese grasshopper and abundant in Gunung Kidul, Yogyakarta, is one such resource (Palupi et al., 2025). Although a small segment of the local population consumes it traditionally, cultural perceptions limit broader acceptance. This species offers a strong nutritional profile, with high protein and omega-3 and omega-6 fatty acid content, despite a fish-like aroma (Żołnierczyk, 2021).

Pempek, a traditional Indonesian food made from fish and tapioca, is known for its distinctive *cuko* sauce and high production capacity (6.4 tons per day). Fish scarcity often limits production, however. Substituting fish with wood grasshopper flour is feasible, given its similar physical properties, particularly its brownish color after processing, and nutrient density comparable to *pempek kulit* (skin fish *pempek*) (Ramadhani et al., 2022). This study aims to develop a functional food formulation that incorporates wood grasshopper flour as a nutrient-dense option to improve maternal nutrition in Indonesia.

METHOD

Research design and sampling

This study used a completely randomized design (CRD) with three independent replications. Treatments consisted of three formulations that varied the proportions of tapioca flour and wood grasshopper (*Valanga nigricornis*): F1 (75:25), F2 (50:50), and F3 (25:75). Raw materials were obtained through purposive sampling in the Gunung Kidul region of Yogyakarta, selected for its biosociocultural relevance, as local communities have traditionally consumed this species (Palupi et al., 2024). The study was conducted from October 2019 to March 2020.

Product formulation and preparation

Product development, from formulation to production, occurred at the Food Processing and Experimental Laboratory, IPB University. Sensory evaluation and acceptance testing took place in the Organoleptic Laboratory, Department of Community Nutrition, Faculty of Human Ecology, IPB University. All analytical procedures followed standardized food analysis protocols.

The *pempek* formulation included wood grasshopper paste (*Valanga nigricornis*) and tapioca flour as main ingredients, with wheat flour and eggs as binding agents. Seasonings consisted of shallots, garlic, scallions, salt, and pepper. The traditional cuko sauce was prepared from palm sugar, chili, and tamarind according to the standard recipe for authentic *pempek* condiments.

Reagents and analytical materials

Reagents and chemicals for chemical analyses included selenium mixtures; 3% boric acid solution (H_3BO_3); Methyl Red and Methyl Blue indicators; concentrated sulfuric acid (H_2SO_4); sodium-EDTA; and sodium hydroxide solutions (30% and 1 N). Additional reagents were 0.1 M hydrochloric acid (HCl), sodium phosphate ($Na_2HPO_4 \cdot 2H_2O$), technical-grade hexane, and analytical enzymes (α-amylase, termamyl, protease, and amyloglucosidase). Organic solvents included 85% and 95% ethanol, methanol, tetrahydrofuran (THF), petroleum ether, and acetone, along with nitric acid (HNO_3), ortho-phthalaldehyde, and a standard amino acid solution (0.5 μmol/mL). Supporting materials such as cotton, deionized water, and distilled water were used as needed.

Laboratory instruments and analytical equipment

Product formulation used standard food processing tools, including grinders, bowls, woks, food scales, stoves, spatulas, pots, knives, and cutting boards. Analytical procedures employed laboratory instruments such as micropipettes, Mohr pipettes, droppers, pipette bulbs, test tubes, syringe filters, watch glasses, oil papers, test tube racks, digestion vessels, magnetic stirrers, hot plates, funnels, Whatman filter paper, furnaces, ovens, desiccators, aluminum and porcelain dishes, graduated cylinders, beakers, water baths, Erlenmeyer flasks, volumetric flasks, glass rods, analytical balances, vacuum pumps, Soxhlet extraction apparatus, and vacuum ovens. Chemical composition analyses were performed using gas chromatography (GC) and inductively coupled plasma optical emission spectrometry (ICP-OES).

RESULTS

Product formulation

Three *pempek* formulations were developed by varying the proportions of wood grasshopper (*Valanga nigricornis*) flour and tapioca flour: F1 (25:75), F2 (50:50), and F3 (75:25). The combined proportion of these flours was fixed at 100% in each formulation. Wheat flour was added to increase sulfur-containing amino acids (Elango & Ball, 2016) and strengthen the dough matrix, which improved texture firmness and reduced cracking during shaping. Formulations were selected based on target attributes: texture, appearance, protein content, and concentrations of zinc, calcium, and iron.

Preparation and processing

Production began with raw material preparation. Wood grasshoppers were briefly blanched in hot water and subsequently cleaned by removing the wings and gastrointestinal contents. The cleaned insects were then immersed in a traditional *bacem* seasoning mixture (garlic with a small amount of palm sugar) for approximately two hours, after which they were stored at approximately −20°C. This marination and chilling step was applied to mitigate the fish-like odor commonly associated with the raw material (Lirizka et al., 2021).

Following marination, the insects were homogenised using a meat grinder to obtain a grasshopper paste. During grinding, non-homogenisable parts (typically residual wing fragments) were separated, yielding approximately 62% of the initial weight. The paste was then mixed with tapioca flour and additional ingredients (egg, wheat flour, scallions, salt, and pepper) until a uniform dough was formed. The dough was shaped into small, bite-sized portions and deep-fried. The final product was served with cuko sauce prepared from palm sugar, chilli, and tamarind, and accompanied by sliced cucumber to enhance perceived freshness and aroma.

Sensory evaluation

Sensory testing was conducted to assess acceptability and preference. Two sequential assessments were applied: a hedonic test (degree of liking), followed by a ranking test. Each formulation was served under a randomised three-digit code to minimise expectation bias and support objective judgement. A total of 30 semi-trained panelists participated; they were recruited based on prior familiarisation with basic sensory procedures and were briefed on the evaluation protocol before testing.

Eligibility criteria included being in good general health, not being acutely hungry at the time of assessment, and having no history of seafood allergy. The seafood-allergy criterion was considered essential given the possibility of allergenic cross-reactivity between crustaceans and edible insects, including grasshoppers (Palupi et al., 2025).

Hedonic rating procedure

Product liking was measured using a 9-point hedonic rating scale in accordance with ISO 8587:1988, ranging from 1 (“dislike extremely”) to 9 (“like extremely”). The evaluated attributes comprised colour, aroma, texture, taste, aftertaste, and overall acceptability of the wood grasshopper *pempek*. Hedonic rating outcomes for each formulation are presented in Table 1.

Table 1. Hedonic rating scores of wood grasshopper (*Valanga nigricornis*) *Pempek*

Attribute	Formula		
	Formula 1	Formula 2	Formula 3
Aroma	6±1,47[a]	6±1,32[a]	7±1,32[a]
Color	5±1,24[a]	5±1,68[a]	3±1,44[b]
Taste	7±0,97[a]	6±1,22[a]	7±1,30[a]
Texture	7±1,04[a]	7±1,40[a]	5±1,08[a]
Aftertaste	7±1,36[a]	6±1,34[a]	7±1,40[a]
Overall	7±1,17[a]	6±1,18[a]	6±1,11[a]

Note: The scale ranges from 1 (strongly dislike) to 9 (strongly like). Different letters in the same row indicate significant differences ($p < 0.05$).

Based on the hedonic test results presented in Table 1, panelists' acceptance of wood grasshopper *pempek* varied across sensory attributes. Overall, all three formulations received favorable responses for taste, aroma, and aftertaste; however, a statistically significant preference difference was observed for color. The Kruskal–Wallis test followed by Mann–Whitney post hoc comparisons confirmed that color was the only attribute that significantly differentiated the samples. F1 and F2 performed comparably ($p > 0.05$) and were preferred over F3 ($p < 0.05$). The mean scores placed F1 and F2 in the "neutral" category (score 5), whereas F3 fell into the "dislike" category (score 3). Visually, panelists perceived F2 as the most similar to traditional *pempek kulit*. In contrast, other sensory attributes (texture, taste, aroma, and aftertaste) were not significantly affected by formulation differences. In terms of overall acceptability, F1 achieved the highest score (score 7), followed by F2 and F3 (both 6). A 9-point hedonic scale is commonly used in consumer sensory evaluation to quantify liking across attributes.

Color represents the first salient visual cue shaping consumer acceptance prior to tasting. Statistical analysis indicated significant differences in color liking ($p < 0.05$), with F1 and F2 receiving comparable acceptance (score 5), while F3 obtained the lowest score (score 3). The pronounced decline in F3 is plausibly attributable to the higher proportion of wood grasshopper material, which may intensify dark pigmentation. Natural melanin pigments associated with the insect exoskeleton, together with Maillard browning during frying (arising from reactions between insect proteins and tapioca-derived carbohydrates), likely produced an excessively dark brown to near black appearance (El Hosry et al., 2025). This visual outcome appears misaligned with panelists' expectations, as *pempek* is typically associated with a lighter or golden-brown color.

For taste, aroma, and aftertaste, no significant differences were detected among treatments, with all formulations consistently scoring within the "like" range (6–7). This pattern suggests that incorporating wood grasshopper at the tested levels—including the highest proportion used in F3—did not deteriorate the typical flavor profile of *pempek*. The relatively high taste scores may be partly explained by naturally occurring glutamic acid, which can contribute an umami-like savory perception, thereby supporting sensory similarity to fish-based *pempek* without reliance on excessive synthetic flavor enhancers.

Regarding texture, although differences were not statistically significant ($p > 0.05$), a downward trend was observed in F3 (mean score 5) compared with F1 and F2 (mean score 7).

This tendency may indicate that high inclusion levels of grasshopper material can influence chewiness and gel structure. Chitin, an insoluble dietary fiber present in insect-derived ingredients (Tain & Hsu, 2024), may interfere with tapioca starch gel formation, potentially yielding a firmer and/or slightly coarser texture than conventional *pempek*. Nevertheless, at the substitution levels used in F1 and F2, texture remained highly acceptable and was perceived as comparable to fish-based *pempek*.

Overall, panelists' ratings across formulations were relatively clustered within the 6–7 range. However, when balancing visual appeal (color) and palatability (taste and texture), F1 and F2 emerged as the most favorable formulations, indicating that wood grasshopper fortification can be sensorially acceptable when applied at moderate substitution levels without compromising the expected organoleptic identity of *pempek*.

Ranking test of wood grasshopper *pempek*

A ranking test was employed to establish the preference order among the developed product formulations, following the general framework of sensory acceptability assessment procedures referenced in ISO 8587:1988. This method was selected due to its time efficiency, applicability across diverse sample matrices, and a straightforward protocol that is typically easy for panelists to follow. In addition, ranking compels panelists to make a clear discrimination among products by assigning a strict order, thereby avoiding tied ranks.

An inherent limitation of ranking methods is that they do not quantify the magnitude of preference differences between samples (i.e., they provide an ordinal order rather than an interval estimate of how much more one sample is preferred than another). During the test, panelists were instructed to rank the three formulas of wood grasshopper *pempek* variants according to overall acceptability, from the most preferred to the least preferred. The ranking outcomes are summarised in Table 2.

Table 2. Ranking test of wood grasshopper (*Valanga nigricornis*) *Pempek*

Wood grasshopper *Pempek*	Mean rank ($\bar{x}$ ±SD)
Formula 1	$1{,}96^{a}$±0,80
Formula 2	$2{,}03^{a}$±0,85
Formula 3	$2{,}00^{a}$±0,83

Notes: Formulations: F1 (75% tapioca flour and 25% wood grasshopper paste); F2 (50% tapioca flour and 50% wood grasshopper paste); F3 (25% tapioca flour and 75% wood grasshopper paste). Different letters within the same column indicate statistically significant differences ($p < 0.05$).

Table 3. Texture analysis of wood grasshopper *pempek*.

Indicator	F1	F2	F3
Texture gram-force (gf)	73,00±2,35[a]	55,66±2,82[a]	35,16±1,64[b]

Notes: Formulations: F1 (75% tapioca flour and 25% wood grasshopper paste); F2 (50% tapioca flour and 50% wood grasshopper paste); F3 (25% tapioca flour and 75% wood grasshopper paste). Different letters within the same column indicate statistically significant differences ($p < 0.05$).

Table 4. T-Test analysis between wood grasshopper *pempek* F1 and F2

Indicator	F1 (x¯±SD)	F2 (x¯±SD)
Protein (% wb)	9,59[a]±0,21	12,41[b]±0,18
Iron (mg/100 g)	2,62[a]±0,24	2,94[b]±0,01

Notes: Formulations: F1 (75% tapioca flour and 25% wood grasshopper paste); F2 (50% tapioca flour and 50% wood grasshopper paste). Different letters within the same column indicate statistically significant differences ($p < 0.05$).

Across formulations F1 and F2 texture test results showed no statistically significant differences (p > 0.05); therefore, texture similarity was considered a key criterion in selecting the optimal formulation. The final selection also incorporated protein and iron contents of F1 and F2, particularly because the hedonic rating indicated a significant difference in color preference between F1 and F2 (p < 0.05). Chemical analysis further demonstrated that F2 contained significantly higher iron and protein levels than F1 (p < 0.05). Accordingly, considering these four decision criteria collectively, formulation F2 (50% wood grasshopper and 50% tapioca flour) was identified as the most suitable formulation.

DISCUSSION

The wood grasshopper *pempek* developed in this study was designed to support the nutritional requirements of pregnant women in accordance with the 2019 Indonesian Recommended Dietary Allowances (AKG 2019), with particular attention to the role of snacks in contributing minimum targets for energy, protein, and fat intake. The production procedure was based on the recipe and processing method of Palembang *pempek kulit*, adapted from Rudi's cookbook. The formulation was established through iterative, trial-based modification of the original recipe, with a key adjustment being the substitution of mackerel skin the primary ingredient in *pempek kulit* with wood grasshopper (Anagonou et al., 2024). In addition, wheat flour was incorporated to improve amino acid score quality (Masrizal & Lamb, 2010), and scallions were added as a flavouring component. These modifications were intended to achieve an optimal balance of nutritional composition, physical texture, and sensory quality (Terstappen et al., 2020).

The development of wood grasshopper (*Valanga nigricornis*) *pempek* as a nutrient-dense alternative food for pregnant women in Indonesia yielded encouraging findings, particularly in terms of sensory attributes and nutritional value. Three formulations—F1 (75% tapioca flour, 25% wood grasshopper), F2 (50% tapioca flour, 50% wood grasshopper), and F3 (25% tapioca flour, 75% wood grasshopper)—were evaluated with reference to texture, appearance, and the protein and iron contents relevant to maternal nutritional needs (Lirizka et al., 2020).

Hedonic ratings for overall acceptability ranged from 6 to 7, indicating that panelists generally "slightly liked" to "liked" the wood grasshopper *pempek*. Kruskal–Wallis testing followed by Mann–Whitney comparisons showed no statistically significant differences ($p > 0.05$) in overall liking among the three formulations. However, for color, the analysis identified a significant difference ($p < 0.05$), specifically between formulation F1 and formulation F2.

Results from organoleptic assessment, comprising both hedonic rating and ranking tests, indicated that F1 and F2 were preferred to F3. Formulation F2 was selected as the best-performing formula because it contained higher protein and iron than F1 and F3 and achieved higher preference on the color attribute, being perceived as closer to Palembang *pempek kulit*. Texture and overall acceptability scores for F1 and F2 were higher, with F1 reaching a hedonic score of 7, suggesting strong panelist preference for its texture and overall product quality. Collectively, these findings suggest that although F3 showed lower acceptance, F1 and F2 provided a more favourable trade off between sensory performance and nutritional value (Fontana et al., 2026).

CONCLUSION

This study successfully substantiates the potential of the wood grasshopper (*Valanga nigricornis*) as a functional substitution ingredient in processed *pempek* products. Sensory evaluation indicated that substitution levels up to 50% (Formulation 2) remained acceptable to consumers, with visual and textural characteristics closely resembling the commercial "*pempek kulit*" variant. Although Formulations 1 and 2 demonstrated comparable hedonic acceptance, chemical analyses showed that Formulation 2 provided a significant nutritional advantage, with higher protein and iron contents than Formulation 1 ($p < 0.05$).

Accordingly, Formulation 2 (50:50 ratio) was identified as the optimal formulation, as it achieves a balance between organoleptic acceptability and nutrient density. This formulation was considered superior because it delivered a sensory profile favoured by panelists—particularly in terms of its resemblance to *pempek kulit*—while also offering significantly higher protein (12.41%) and iron (2.94 mg/100 g) than the other formulations. This innovation has strong potential for further development as a local food-based strategy to help address anemia and chronic energy deficiency (CED) among pregnant women in Indonesia, while also supporting the broader advancement of insect-based foods as a practical response to malnutrition.

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