

## Cassava *Lanting* Substituted with Mole Crab (*Emerita emeritus*) Flour to Increase Calcium Content

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### ABSTRACT

The fact that most Indonesians only get about 40% of the suggested daily allowance of calcium shows how important it is to come up with new foods that use calcium-rich local ingredients. Mole crab (*Emerita emeritus*), a crustacean that lives along the southern coast of Java, has a lot of calcium and could be used instead of other ingredients in some traditional foods. This study contributed the best mole crab flour substitution in cassava-based *lanting* formulation and evaluated its chemical and sensory properties. Three replications were used in a completely randomized design with a single factor, mole crab flour replacement amounts of 0, 5, 10, 15, and 20% (P0–P4). Hedonic evaluation, nutritional value calculation, moisture, ash, fat, protein, carbohydrate, and calcium content were evaluated. The results demonstrated that increasing levels of mole crab flour substitution significantly enhanced calcium, protein, and ash contents, while moisture content decreased and fat content fluctuated. Sensory evaluation showed that panelist acceptance of appearance, texture, and taste improved up to the optimum formulation at P2, then declined at higher substitution levels due to the dominance of fishy odor and flavor. Based on the exponential comparison method, P2 was selected as the best formulation because it provided the most balanced improvement in nutritional quality and sensory acceptability, contributing approximately 15% of the daily value for calcium per serving. These findings suggest that mole crab flour substitution in *lanting* could help communities in southern Java construct calcium-rich functional native meals to boost mineral intake.

### KEYWORDS

Calcium content; Cassava *lanting*; Mole crab flour; Sensory characteristics; Substitution formulation

## 1. INTRODUCTION

Calcium is an essential mineral that performs critical physiological functions, ranging from neural signal transmission to bone mineralization. Approximately 99% of body calcium is stored in bones and is regulated through a hormonal system involving parathyroid hormone (PTH) and vitamin D [1]. Chronic calcium deficiency has been associated with osteoporosis, impaired bone mineralization, and osteomalacia [2]. According to the Regulation of the Minister of Health of the Republic of Indonesia No. 28 of 2019, the recommended daily calcium intake is 1,000 mg for adults and 1,200 mg for adolescents. However, the average calcium intake among the Indonesian population is only approximately 457 mg/day, equivalent to around 40% of the recommended dietary allowance [3]. This issue reflects not only insufficient dietary intake but also limited access to affordable and culturally acceptable calcium-rich food sources.

One potential strategy to address this problem is food diversification based on local ingredients through the substitution of raw materials in traditional food products. *Lanting*, a traditional snack originating from Kebumen and characterized by its ring or figure-eight shape, is widely accepted by consumers across various age groups [4]. Nevertheless, nutritionally, its main ingredient cassava is predominantly composed of carbohydrates, ranging from 25,300 to 35,700 mg/100 g, while its calcium content remains relatively low at only 19–176 mg/100 g [5]. Consequently, although *lanting* is highly

popular, its contribution to calcium intake is minimal, thereby supporting the need for partial substitution with calcium-rich ingredients.

The mole crab (*Emerita emeritus*) is an intertidal crustacean commonly found along the southern coast of Java and has been reported to possess a substantial mineral profile. The mole crab population along the Cilacap coast, Central Java, consists of two sympatric species, namely *Emerita emeritus* and *Emerita* sp., with *Emerita* sp. exhibiting higher abundance and greater haplotype diversity ( $0.857 \pm 0.057$ ) [6]. Mole crab flour contains calcium at 8,770 mg/100 g and phosphorus at 820 mg/100 g on a dry-weight basis [7], while other studies reported calcium levels reaching 2,689.72 mg/100 g dry weight [8]. These values are considerably higher than those of conventional plant-based calcium sources and are comparable to various crustacean-derived products. Mole crabs from the family *Hippidae* have also been confirmed to contain protein, fat, and minerals in proportions suitable for functional food applications [9]. Furthermore, the shells of *Emerita emeritus* are rich in chitin, which can be processed into chitosan possessing antioxidant and antimicrobial properties, suggesting additional potential benefits for food safety and preservation [10].

Scientific evidence regarding the utilization of crustacean shell flour as a substitution ingredient in food products has been widely reported. Substitution of crab shell flour in bread increased calcium content to 31.75–31.96 mg/100 g without significantly reducing sensory acceptance [11]. Likewise, the incorporation of mangrove crab shell flour (*Scylla serrata*) into cookies increased calcium content proportionally with substitution level, from 6.53 mg/100 g in the control to 180.28 mg/100 g at 15% substitution [12]. Collectively, these findings demonstrate that crustacean flour substitution represents an effective and measurable approach to improving the mineral density of food products. However, the application of mole crab flour in *lanting* has not yet been scientifically investigated. Previous studies have only evaluated its utilization in stick-type snacks, where substitution increased calcium content up to 2,885 mg/100 g [8]. The novelty of the present study lies in three aspects: first, the evaluation of mole crab flour substitution in a cassava-based fried food matrix with processing characteristics distinct from previously studied products; second, the determination of an optimal substitution formulation that balances calcium enrichment and sensory acceptance; and third, the development of a local food diversification model potentially applicable to various cassava-based products such as chips, sticks, and extruded snacks.

Based on this rationale, the present study contributed to determine the optimal formulation of mole crab flour substitution in *lanting* and to evaluate its chemical and sensory characteristics. The expected outcomes include the utilization of mole crab as a novel resource for food diversification, the expansion of its application in cassava and tuber-based products, and the development of alternative functional foods that support sustainable calcium intake. This study contributes formulation-based scientific evidence regarding mole crab flour substitution in *lanting* as a model for the development of high-calcium local food products accessible to the wider community, particularly in the southern coastal regions of Java where mole crab resources are abundant.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The materials used consisted of cassava obtained from local farmers in Wonosobo Regency, Central Java, and mole crabs collected from coastal harvesters along the southern coast of Java Island, specifically Glagah Beach, Special Region of Yogyakarta. In addition to these primary materials, supporting ingredients included garlic, salt, and a flavor enhancer (Royco, Indonesia). Chemical reagents used in the analysis included 3%  $H_3BO_3$  (Merck, Germany), 0.1% bromocresol green, 0.1% methyl red, 95% ethanol (Sigma-Aldrich, United States), 0.02 N HCl (Merck, Germany), Kjeldahl tablets (Merck, Germany), 30–33% NaOH (Merck, Germany),  $HNO_3$ , HCl, and 60%  $HClO_4$  (Merck, Germany), ammonium oxalate (Sigma-Aldrich, United States), and  $CaCO_3$  (Sigma-Aldrich, United States).

### 2.2. Research Design

The research was designed as an experiment following a Completely Randomized Design (CRD) that involved one experimental factor, specifically the concentration of mole crab flour substituted into cassava *lanting* products. The treatments consisted of P0 (0%), P1 (5%), P2 (10%), P3 (15%), and P4 (20%),

each with three replications. The study consisted of three main stages: (1) preparation of mole crab flour, (2) production of cassava *lanting* with mole crab flour substitution according to the treatment concentrations, and (3) product evaluation, which included proximate composition analysis (moisture, ash, fat, protein, and carbohydrate contents), calcium content analysis, hedonic testing (appearance, odor, taste, and texture), and calculation of Nutrition Facts (NF).

### 2.3. Preparation of Mole Crab Flour

The method employed in this study was adapted from a previously published study with several adjustments introduced in the present research [8]. Initially, the collected mole crabs were rinsed with running water to eliminate adhering sand and other impurities, followed by trimming to remove the head and tail parts. The material was then steamed for 15 minutes until cooked and subsequently sun-dried for two days until completely dry. Once drying was completed, the material was milled with a mechanical grinder to produce mole crab flour, and the processing stages are illustrated in Figure 1.

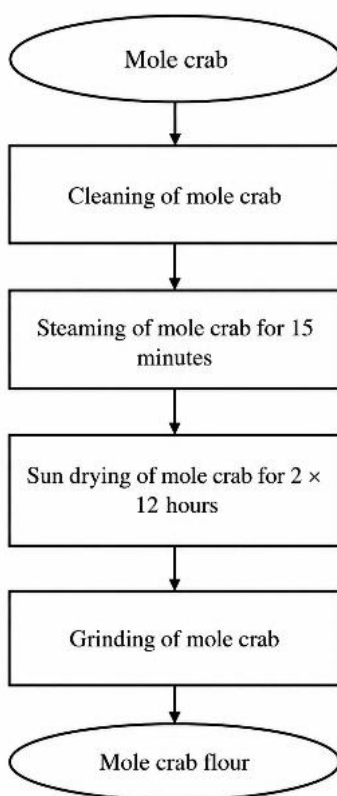


Figure 1. Flowchart of mole crab flour preparation.

### 2.4. Lanting Preparation

The formulation for producing *lanting* with substitution of mole crab flour was based on the recipe used by small-scale *lanting* producers in Patukrejo Village, with several adjustments to the processing steps. The production process began with the preparation of cassava as the main raw material, which was peeled, thoroughly washed, grated, and then squeezed to reduce its moisture content. Subsequently, a portion of the material was substituted with mole crab flour according to the concentration levels specified in the formulation. The dough was then mixed with additional ingredients such as garlic, salt, and flavor enhancers until evenly combined. The mixture was steamed for 12 minutes and immediately shaped while still hot. The formed *lanting* was then dried under sunlight for two days until the desired dry texture was obtained. After drying, the product was fried in hot vegetable (palm) oil at a temperature of 160–180 °C for 3 minutes. The detailed formulation is presented in Table 1, while the processing steps are illustrated in Figure 2.

Table 1. Formulation of mole crab *lanting*.

Ingredients (g)	P0	P1	P2	P3	P4
Cassava	500	475	450	425	400
Mole crab flour	0	25	50	75	100
Salt	9	9	9	9	9
Flavor enhancer	0.6	0.6	0.6	0.6	0.6
Garlic	0.3	0.3	0.3	0.3	0.3

Note: Composition of ingredients in *lanting* formulation based on 500 g total flour.

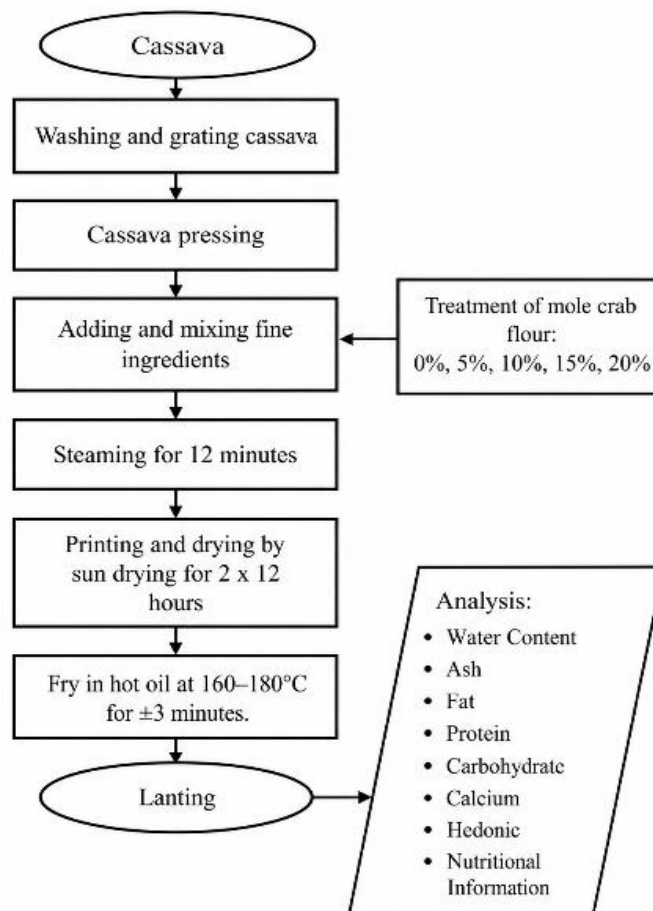


Figure 2. Flowchart of substituted *lanting* preparation.

## 2.5. Moisture Content Analysis

Moisture content was calculated based on the weight difference between the material prior to drying and after the drying process. The procedure began by heating the weighing dish at 100–105 °C in a drying oven for approximately 30 minutes. Subsequently, the dish was allowed to cool inside a desiccator before its mass was recorded as the dish's starting mass (A). Subsequently, approximately 1 g of material was placed into the dish, and the combined mass of the dish with the material was recorded as the initial mass (B). Next, the material underwent heating in a drying oven maintained at 100–105 °C for approximately 6 hours. Afterward, it was allowed to reach room temperature inside a desiccator for about 30 minutes before its mass was recorded as final mass (C). Moisture content was determined based on the equation (1).

$$\text{Moisture content (\%)} = \frac{(B - C)}{(B - A)} \times 100\% \quad (1)$$

## 2.6. Ash Content Analysis

Ash content analysis in this study was conducted using the dry ashing method [13], which is based on the principle of combusting the sample at high temperatures until all organic components are oxidized, leaving an inorganic residue in the form of ash. The procedure began by heating the crucible in a drying oven maintained at 100–105 °C for approximately 30 minutes or until its mass remained unchanged. Afterward, the crucible underwent stabilization in a desiccator for approximately 30 minutes, after which its mass was recorded as initial crucible mass (A). Subsequently, approximately 1 g of material was placed into the crucible, and the combined mass of the crucible containing the material was recorded as the starting mass (B). Next, the crucible containing the material underwent ashing inside a muffle furnace maintained at 400 °C until a grayish mineral residue formed and the mass remained stable. Subsequently, the furnace temperature was raised to 550 °C and maintained within a duration of 12–24 hours to ensure complete decomposition of all organic constituents. After ashing, the material was allowed to stabilize in a desiccator for approximately 30 minutes, after which its mass was recorded as final mass (C). Ash content was determined based on the equation (2).

$$\text{Ash content (\%)} = \frac{(C - A)}{(B - A)} \times 100\% \quad (2)$$

## 2.7. Fat Content Analysis

Fat content in this study was analyzed through Soxhlet extraction method [13]. The procedure started with preparing a fat flask according to the apparatus size. The flask was dried in an oven, allowed to stabilize inside a desiccator, and its mass was repeatedly measured until a stable initial mass was reached. A powdered sample weighing 1 g was weighed and placed into a thimble or filter paper, then covered with cotton or tightly wrapped before being placed in the Soxhlet apparatus assembled with a condenser at the top and a fat flask at the bottom. Solvent was introduced into the fat flask, and extraction proceeded through refluxing for a minimum duration of 5 hours until the returning liquid became clear, after which the remaining solvent was removed by distillation. A fat flask with the extracted lipid was subsequently heated at 105 °C to eliminate residual solvent, placed in a desiccator to stabilize its mass, and remeasured to determine the mass difference before and after extraction. Fat content was determined by applying the equation (3), where  $W_2$  was weight of flask and extracted lipid after drying (g),  $W_1$  was weight of empty flask (g), and  $W$  was weight of initial sample (g).

$$\text{Fat content (\%)} = \frac{W_2 - W_1}{W} \times 100\% \quad (3)$$

## 2.8. Protein Content Analysis

Protein content in this study was analyzed through the Kjeldahl procedure SNI 01-2354.4-2006. The sample consisted of cassava *lanting* derived through formulations incorporating homogenized mole crab flour substitution. Approximately 2 g of material were measured, enclosed in weighing paper, and transferred into a digestion vessel. The digestion mixture underwent stepwise incorporation of catalyst tablets, anti-bumping granules, 15 mL sulfuric acid (95–97%), together with 3 mL hydrogen peroxide, after which the solution remained in the fume hood for roughly 10 minutes. A temperature close to 410 °C maintained digestion for about 2 hours, leading to formation of a clear solution. After completion of digestion, cooling under ambient conditions preceded dilution using 50–75 mL distilled water. Subsequently, distillation through a steam driven distillation system occurred after introducing 50–75 mL sodium hydroxide thiosulfate reagent. Distillation output entered a receiving erlenmeyer vessel filled with 25 mL of 4%  $H_3BO_3$  together with an indicator, and accumulation continued until a minimum volume of 150 mL had been obtained. The distillate subsequently underwent titration using 0.2 N hydrochloric acid, with the endpoint indicated by a visual shift in indicator appearance, changing from green to neutral gray.

Control determination followed an identical analytical process in the absence of test material, while every analysis occurred at least in duplicate. Calculation of protein content (%) relied on the equation (4), where VA is sample titration volume (mL HCl), VB is blank titration volume (mL HCl), N is normality of HCl, 14.007 is atomic weight of nitrogen, 6.25 is protein conversion factor, W is sample weight (g), and protein content expressed as g/100 g sample (%).

$$\text{Protein content (\%)} = \frac{(VA - VB) \times N \times 14.007 \times 6.25}{W \times 1000} \times 100\% \quad (4)$$

## 2.9. Carbohydrate Content Analysis

Carbohydrate content was estimated using an indirect calculation approach, in which the carbohydrate fraction resulted from subtracting 100% after accounting for previously measured moisture, ash, protein, and fat content [13]. Using this method, carbohydrate content is obtained as the remaining fraction of the total nutritional components after deducting the other constituents. This approach was used because carbohydrate values are related to the composition of other nutrients; therefore, changes in one component will affect the calculated carbohydrate content. Carbohydrate content (%) was determined based on the equation (5), where A is moisture content (%wb), B is ash content (%wb), C is protein content (%wb), and D is fat content (%wb).

$$\text{Carbohydrate content (\%)} = (100\% - A - B - C - D) \quad (5)$$

## 2.10. Calcium Content Analysis

Quantification of calcium content employed Inductively Coupled Plasma–Optical Emission Spectrometry (ICP-OES) [14]. Approximately 0.5 g of homogenized solid material underwent measurement and transfer into a microwave digestion vessel, after which concentrated HNO<sub>3</sub> (p.a.) entered the vessel. The mixture was allowed to stand for approximately 15 minutes to allow a pre-reaction before being digested using a microwave digester until a clear solution was obtained after digestion, cooling occurred under ambient conditions, followed by quantitative transfer of digest into a 50 mL volumetric vessel. Internal standard such as yttrium entered the mixture; subsequent dilution reached calibration level using ultrapure liquid, followed by homogenization prior filtration before analysis. Determination of calcium concentration utilized ICP-OES with detection based on a characteristic emission line of Ca, while quantification relied on a calibration curve generated from no fewer than 6 levels of calcium standards. Quantification of calcium relied on a linear regression model developed from calibration standards, as indicated in the equation (6), where A<sub>spl</sub> is emission intensity of calcium in the sample, a is intercept of the calibration curve, b is slope of the calibration curve, V is final volume of the test solution (mL), fp is dilution factor, and W<sub>spl</sub> is sample weight (g).

$$\text{Calcium (Ca) content (mg/kg)} = \frac{(A_{\text{spl}} - a)}{b} \times \frac{V \times \text{fp}}{W_{\text{spl}}} \quad (6)$$

## 2.11. Hedonic Test

Hedonic testing was conducted in accordance with standard sensory evaluation guidelines, using a minimum of 25–30 untrained panelists consisting of both males and females with a balanced gender distribution (± 50% male and ± 50% female), aged between 18 and 55 years, to assess consumer preference for the tested products [15]. Panelists were selected based on several screening criteria aligned with quantitative affective testing principles, including the absence of sensory impairments (e.g., anosmia, hyposmia, or taste disorders), not being in a state of illness or under medication that could affect sensory perception, refraining from smoking at least 30 minutes prior to testing, having no known allergies to the tested food ingredients, and being willing to follow all procedures while providing independent and unbiased evaluations; the number of screened candidates was recommended to be at least twice the required number of panelists. All participants took part voluntarily and provided written informed consent prior to

the evaluation, with the protocol adhering to ethical principles for human subject research, including confidentiality of personal data, the right to withdraw at any time without consequences, and assurance that all samples were safe and met food hygiene standards. Samples were prepared in uniform size and quantity, coded with random three-digit numbers to minimize bias, and presented in a randomized order under identical conditions, while panelists evaluated appearance, odor, taste, texture, and overall acceptability using a nine-point hedonic scale (1–9), ranging from “dislike extremely” to “like extremely,” with responses recorded on prepared evaluation forms.

### 2.12. Nutrition Calculation

Nutrition Information (NI) refers to information regarding the content of nutrients and non-nutrients in processed food products presented in a standardized format according to the marketed product and supported by results from accredited laboratory analyses. Elements presented in the Nutrition Information table include serving size, number of servings per package, categories and quantities of nutrients and non-nutrients, the percentage of Recommended Dietary Allowance (%RDA), together with explanatory footnotes, prepared in accordance with guidelines issued by *Badan Pengawas Obat dan Makanan Republik Indonesia* (BPOM-RI). RDA indicates a nutrient consumption reference designed to fulfill nutritional requirements for most healthy members of a population, considering life stage, sex, along with particular physiological conditions. Nutrient reference values encompass energy, protein, carbohydrate, and fat components, while calculation procedures follow the Nutritional Label Reference issued by BPOM-RI. The calculation of Nutrition Information values can be determined using the equation (7).

$$\%RDA = \frac{\text{Nutrient content}}{(\text{RDA}) \text{ of the nutrient}} \times 100\% \quad (7)$$

### 2.13. Data Analysis

Interpretation of research findings employed descriptive and comparative approaches to generate conclusions. Hedonic, proximate, along with calcium measurements underwent statistical processing through SPSS version 20. Evaluation of hedonic responses applied a non-parametric Kruskal Wallis approach, with pairwise comparison performed through the Mann–Whitney method when statistical variation occurred. In contrast, proximate composition and calcium measurements underwent variance analysis with  $\alpha = 0.05$ , followed by Duncan’s multiple range procedure whenever treatment effects appeared.

## 3. RESULTS AND DISCUSSION

### 3.1. Moisture Content

The ANOVA results showed that substitution of mole crab flour significantly reduced the moisture content of *lanting* compared to P0 ( $p < 0.05$ ), with a consistent decreasing trend as the substitution level increased (Table 2). This decrease was closely related to the composition of mole crab flour which is rich in protein (40.48%) and ash (16.33%), in contrast to cassava flour which is dominated by starch with low protein content (<2%) and limited minerals [16]. This finding is in line with a study of extruded products enriched with fish meal and shrimp head waste, with moisture content ranging from 7.92–9.87% [17], indicating that crustacean-based ingredients tend to produce products with low and controlled moisture content.

Mechanistically, the decrease in moisture content can be explained through several chemical interactions in food. Although proteins have the capacity to bind water, protein denaturation during frying actually releases bound water and accelerates evaporation [18]. Mineral content, particularly calcium, forms a denser matrix, reducing the system's ability to retain free water. In starch components, gelatinization followed by partial retrogradation reduces water-binding stability. During frying, mass transfer in the form of evaporation of water from the interior to the surface is replaced by oil, accompanied by the formation of pores due to vapor pressure [19]. The maillard reaction and protein denaturation contribute to the formation of a crust that accelerates dehydration and reduces water activity, thereby increasing crispiness and

extending shelf life [20]. However, too low a water content can potentially result in a texture that is too hard [21]. However, all substitution treatments produced water content below the maximum limit of 12% according to SNI 2713.1:2009, thus meeting quality standards and having the potential to be developed as a high-calcium functional food product.

Tabel 2. Proximate composition of *lanting* substituted with mole crab flour.

Treatment	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
P0	6.69 ± 0.12 <sup>a</sup>	3.38 ± 0,12 <sup>a</sup>	28.0 ± 1.0 <sup>a</sup>	0.88 ± 0.01 <sup>a</sup>	61.05 ± 1.01 <sup>b</sup>
P1	4.11 ± 0.29 <sup>b</sup>	4.86 ± 0,06 <sup>b</sup>	22.0 ± 3.0 <sup>ab</sup>	4.94 ± 0.13 <sup>b</sup>	64.09 ± 3.02 <sup>b</sup>
P2	4.15 ± 0.18 <sup>b</sup>	5.23 ± 0,00 <sup>b</sup>	29.5 ± 3.5 <sup>a</sup>	5.30 ± 0.04 <sup>c</sup>	55.82 ± 3.50 <sup>a</sup>
P3	4.15 ± 0.15 <sup>b</sup>	6.88 ± 0,11 <sup>c</sup>	13.5 ± 0.5 <sup>b</sup>	7.96 ± 0.08 <sup>c</sup>	67.51 ± 0.53 <sup>c</sup>
P4	3.16 ± 0.17 <sup>c</sup>	7.25 ± 0,40 <sup>c</sup>	16.5 ± 3.5 <sup>b</sup>	7.60 ± 0.08 <sup>d</sup>	65.49 ± 3.53 <sup>c</sup>

Note: Data are presented as average values accompanied by standard deviation based on three replications. Distinct superscript letters within a column denote statistical variation at  $p < 0.05$  identified through analysis of variance with Duncan's multiple range comparison.

### 3.2. Ash Content

The ANOVA results showed that the substitution of mole crab flour had a significant effect ( $p < 0.05$ ) on the ash content of cassava-based *lanting* compared to the control (P0), with a linear increase as the substitution level increased until it reached the highest value in treatment P4 (Table 2). This increase was directly correlated with the mineral composition of mole crab flour which contained an ash content of 16.33% with the main minerals being calcium (26.52 mg/g), magnesium (10.20 mg/g), and iron (0.04 mg/g) [8], much higher than cassava flour with an ash content of around 2.89% [22]. A similar trend was found in cereal-based extruded products substituted with fish meal and shrimp head extract, where the ash content increased from 1.03% (control) to 1.21% with the addition of 2.5% fish meal, and reached 1.28% when combined with shrimp head extract [23].

Mechanistically, ash content reflects the inorganic residue after the degradation of organic components, thus representing the total minerals in food [24]. Minerals such as calcium, magnesium, and phosphorus are heat-stable and do not degrade during processing, including frying [25]. At high temperatures, water evaporation, protein denaturation, and starch gelatinization produce a more compact matrix so that minerals are trapped and distributed evenly in the product [19]. In addition, protein-starch interactions through hydrogen, electrostatic, and hydrophobic bonds form a complex network that enhances mineral retention in the food matrix [26]. Thus, the increase in ash content is influenced by the initial mineral composition and its stability and retention during processing, which overall contributes to increasing the nutritional value of the product as a source of essential minerals [27].

### 3.3. Fat Content

The ANOVA results showed that the substitution of mole crab flour had a significant effect ( $p < 0.05$ ) on the fat content of cassava-based *lanting* (Table 2). The fat content showed a fluctuating pattern, with the most significant decrease in P3 and a slight increase in P4, which was not significantly different from P3. This pattern was influenced by the composition of the raw materials and the dynamics of oil absorption during frying. Mole crab flour contains lipids rich in unsaturated fatty acids such as EPA and DHA [28], while cassava flour only contains about 1.14 g/100 g of fat [29]. This finding is in line with a study of snacks enriched with shrimp head autolysate, where the fat content increased from 20.58% (control) to 27.68% at 5% substitution, then decreased to 24.38% at 10% substitution [30].

Mechanistically, fat content is influenced by the lipid composition of the raw material and mass transfer phenomena during frying. At high temperatures, water in the material evaporates rapidly, forming a positive pressure gradient that forces steam out through pores, capillaries, and microcracks, resulting in the formation of a surface crust and increasing the porosity of the structure, which serves as a pathway for oil penetration [31]. Oil absorption occurs through a water-oil replacement mechanism and a cooling effect, where water vapor condensation reduces internal pressure so that oil is drawn in through capillary forces,

with the amount of absorbed oil positively correlated with water loss and the pore characteristics of the product [32]. Increasing fat content can increase energy value and flavor, but has the potential to reduce oxidative stability and shelf life if not controlled [33]. Nevertheless, all treatments produced fat content below the maximum limit of 38% according to SNI 01-2886-2000, thus meeting applicable quality standards.

### 3.4. Protein Content

The ANOVA results showed that the substitution of mole crab flour had a very significant effect ( $p < 0.05$ ) on the protein content of cassava-based *lanting* compared to the control (P0) (Table 2). Protein content increased with increasing substitution levels up to the optimum point, then decreased slightly at the highest concentration (P4), although it remained higher than the control. This increase was related to the protein content of mole crab flour which reached 32.42% [34], thus contributing directly to the increase in product protein. The decrease in P4 was thought to be due to protein denaturation by high frying temperatures and the maillard reaction which reduced the availability of free amino acids [35]. This finding is consistent with the substitution of shrimp shell flour in tempeh steak which increases protein from 17.67% to 21.79% at 15% substitution, then slightly decreases to 21.75% at 20% substitution [36].

Mechanistically, changes in protein content are influenced by complex interactions between protein, starch, and non-protein components in the food matrix. Protein denaturation due to heat changes the tertiary and quaternary configurations, which can reduce protein solubility and bioavailability [35]. The maillard reaction between protein amino groups and reducing sugar carbonyl groups produces melanoidins and reduces the availability of essential amino acids such as lysine, which impacts protein quality and DIAAS values [37]. Starch-protein interactions form a matrix that affects the physicochemical properties and digestibility of starch during heating, including the formation of a more compact starch granule structure that inhibits gelatinization [26]. In addition, chitin from crustaceans competes for water binding, thus affecting water distribution and protein stability in the dough matrix [38]. Although heating has the potential to reduce protein quality, all treatments still meet the quality standards of SNI 8272:2016.

### 3.5. Carbohydrate Content

The ANOVA results showed that the substitution of mole crab had a very significant effect ( $p < 0.05$ ) on the carbohydrate content of *lanting* compared to P0 (Table 2). The carbohydrate content showed a fluctuating pattern as the substitution level increased, which was mathematically influenced by the difference method, namely carbohydrates were calculated as the remaining 100% after subtracting the water, ash, protein, and fat content [39]. Thus, increasing other proximate components especially protein and ash from mole crab flour directly reduced the percentage of carbohydrates in the product. This finding is consistent with studies of biscuits fortified with fish flour, with a carbohydrate content of around 63.52% which tended to be lower than unfortified products [40], as well as tempeh steak substituted with shrimp shell flour, where carbohydrates decreased from 25.30% to 24.56% [36].

Mechanistically, carbohydrate content is highly dependent on changes in other components such as protein, fat, and ash [39]. During processing, starch undergoes gelatinization, a phase transition from a regular to a disordered structure that irreversibly disrupts the semi-crystalline structure, thus affecting the texture and digestibility of starch-based products [41]. The interaction of starch with protein and fat forms a complex matrix through hydrogen, hydrophobic, and electrostatic bonds that affect starch availability during processing [42]. The presence of protein in the food matrix can also inhibit gelatinization, reduce viscosity, and slow starch hydrolysis and digestibility [43]. Therefore, changes in carbohydrate content are not only mathematical but also reflect structural modifications of starch and its interactions with other components during processing, ultimately affecting the nutritional value of the product [44].

### 3.6. Calcium Content

The ANOVA results showed that the substitution of mole crab flour had a significant effect ( $p < 0.05$ ) on increasing the calcium content of cassava-based *lanting* compared to the control (P0), with a linear increasing trend as the substitution level increased to the highest value in treatment P4 (Figure 3). This

increase was related to the high mineral content of crustacean exoskeletons, which were dominated by calcium in the form of calcium carbonate ( $\text{CaCO}_3$ ) and calcium phosphate, covering approximately 40–70% of the total composition [45]. The calcium content of mole crab flour reached 2,652 mg/100 g and increased to 2,885 mg/100 g after processing [8], much higher than cassava flour which only ranged from 0.094–0.134 mg/100 g [46]. This finding is consistent with the substitution of catfish head flour in crackers which increases calcium from 380.17 mg/100 g to 393.92 mg/100 g [47], as well as the fortification of shrimp shell flour in bread which increases calcium from 1.465 mg/100 g to 30.095 mg/100 g [48].

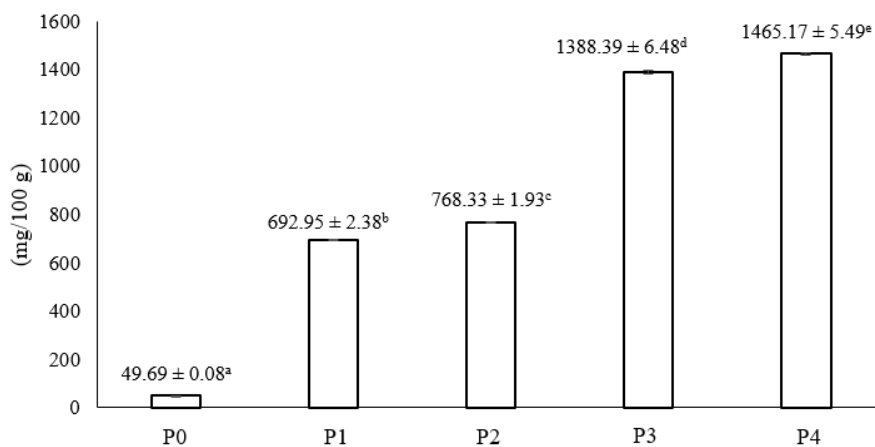


Figure 3. Mean calcium levels in *lanting* products. Distinct superscript notations represent statistically significant variation among treatments ( $p < 0.05$ ).

### 3.7. Hedonic Test Result

Hedonic evaluation outcomes for cassava *lanting* formulated with mole crab flour substitution can be seen in Table 3. The substitution level influenced panelists preferences for appearance, odor, taste, and texture. Among the treatments, P2 showed relatively higher acceptance compared to other treatments.

Table 3. Results of hedonic test analysis of the product.

Parameter	Mean Value of Hedonic Test				
	P0	P1	P2	P3	P4
Appearance	6.63 ± 1.245 <sup>ab</sup>	6.87 ± 1.224 <sup>abc</sup>	7.27 ± 1.015 <sup>c</sup>	7.23 ± 0.898 <sup>bc</sup>	6.37 ± 1.629 <sup>a</sup>
Odor	6.23 ± 1.406 <sup>a</sup>	6.37 ± 1.351 <sup>a</sup>	6.8 ± 1.243 <sup>a</sup>	6.73 ± 1.388 <sup>a</sup>	6.13 ± 1.252 <sup>a</sup>
Texture	5.53 ± 2.013 <sup>a</sup>	7.17 ± 1.315 <sup>bc</sup>	7.63 ± 1.159 <sup>c</sup>	7.2 ± 1.424 <sup>bc</sup>	6.57 ± 1.357 <sup>ab</sup>
Taste	6.63 ± 1.497 <sup>b</sup>	7.27 ± 1.285 <sup>bc</sup>	7.47 ± 1.167 <sup>c</sup>	7.1 ± 1.213 <sup>bc</sup>	5.73 ± 1.574 <sup>a</sup>

Note: Results are reported as the mean together with the standard deviation. Distinct superscript letters within a row denote statistically significant differences at  $p < 0.05$ .

#### 3.7.1. Appearance

The appearance of cassava *lanting* with mole crab flour is shown in Figure 4. The Kruskal Wallis test results showed that substitution of mole crab flour had a significant effect ( $p < 0.05$ ) on the hedonic appearance score of cassava-based *lanting* (Figure 5). Panelist acceptance showed a fluctuating pattern, increasing to an optimum point at P2 and then decreasing at higher concentrations. This indicates that the balance between the natural color of cassava and the pigments from the substituted ingredients plays an important role in the product's visual appeal. At moderate levels of substitution, the resulting color was considered brighter and more attractive, while excessive substitution resulted in a darker color that decreased panelist preference. This finding is in line with a study of milkfish pempek which showed that the color score increased from 4.10 (control) to 4.20 at 10% substitution, then decreased at 15% substitution due to excessive color intensity [49]. A similar trend was found in croissants with shrimp shell flour

substitution, where the highest appearance score reached 7.10 at 5% substitution and decreased at higher concentrations [50].

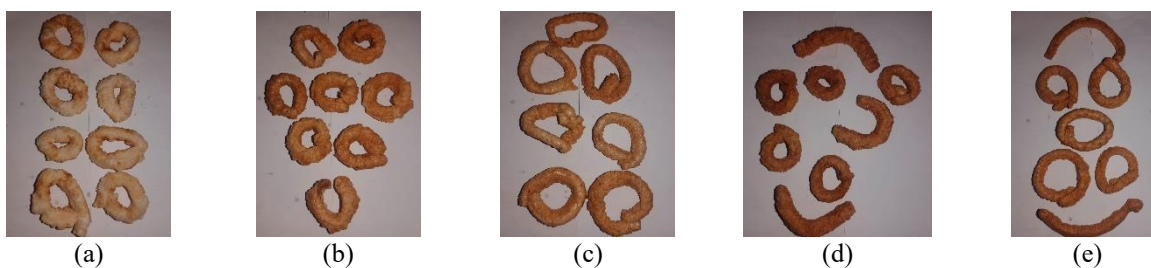


Figure 4. Physical appearance of cassava *lanting* with mole crab flour substitution. (a) P0: control (0% substitution); (b) P1: 5% substitution; (c) P2: 10% substitution; (d) P3: 15% substitution; (e) P4: 20% substitution.

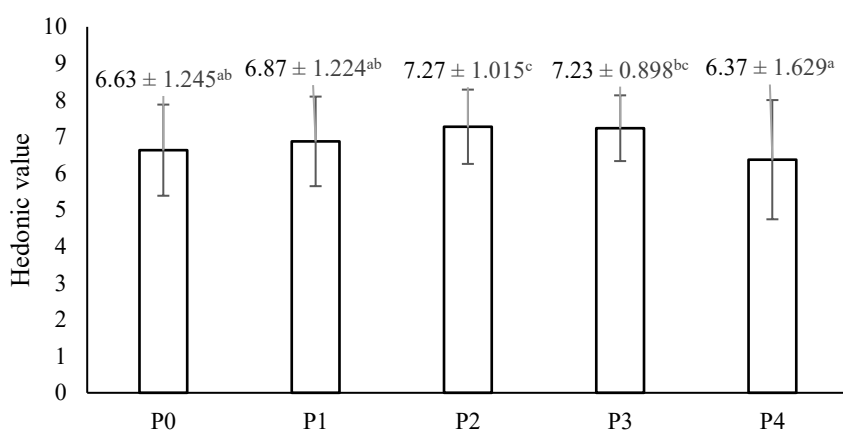


Figure 5. Mean appearance ratings for *lanting*. Distinct superscript letters represent statistically meaningful variation among values ( $p < 0.05$ ).

Mechanistically, changes in the appearance of fried products are primarily influenced by the maillard reaction and carotenoid pigment degradation. The maillard reaction is a non-enzymatic browning process between the amino groups of proteins and the carbonyl groups of reducing sugars, which occurs through the formation of Schiff bases, Amadori products, to produce dark brown melanoidins [37]. The addition of protein-rich mole crab flour increases the availability of free amino groups, thus accelerating the browning rate. On the other hand, astaxanthin, the main pigment in crustaceans, is susceptible to isomerization and oxidation during heating, causing the loss of its characteristic red-orange color and the formation of volatile compounds [51]. This process is enhanced by lipid oxidation during frying, which produces free radicals, thus accelerating pigment degradation and further browning reactions [52]. Thus, moderate browning can increase product appeal, while excessive browning actually decreases consumer acceptance due to the color being too dark [53].

### 3.7.2. Odor

The Kruskal Wallis test results showed that the substitution of mole crab flour did not significantly affect the hedonic score of fried cassava *lanting* odor in all treatments ( $p > 0.05$ ) (Figure 6). All samples obtained the same notation (<sup>a</sup>) with a mean score ranging from 6.13–6.80, indicating that panelist acceptance remained stable up to the highest substitution level (P4). This finding is in line with other research who reported that the addition of shrimp waste flour up to 15% in milkfish pempek did not produce significant differences in odor attributes ( $p > 0.05$ ) [54]. In general, these results indicate that the use of crustacean-based ingredients within a certain range does not significantly affect the product odor, possibly due to a

balance between the odor of the main raw material and the volatile compounds from the substituted ingredients.

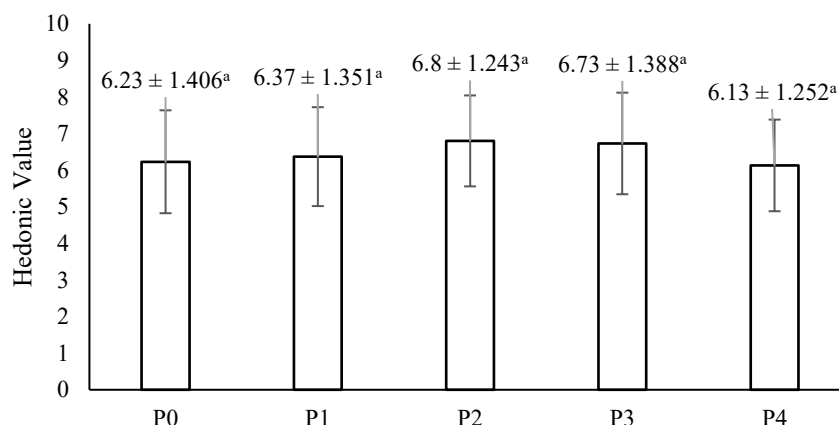


Figure 6. Mean odor ratings for *lanting*. Distinct superscript letters represent statistically comparable values ( $p > 0.05$ ).

Mechanistically, the odor of fried products is formed from various volatile compounds produced during heating, mainly through the oxidation of unsaturated fatty acids that produce aldehydes (pentanal, hexanal, heptanal, and octanal), ketones, and alcohols that contribute to the characteristic odor of fried foods [55]. The maillard reaction between amino acids and reducing sugars also plays an important role in odor formation through the production of pyrazines and Strecker aldehydes such as benzaldehyde and 3-methylbutanal that produce savory and roasted odors [56]. In seafood-based ingredients, trimethylamine oxide (TMAO) can degrade to trimethylamine (TMA) during heating and contribute to the fishy odor [57]. However, TMA does not dominate because it is masked by the pyrazines and other aldehydes formed [58]. Furthermore, astaxanthin in diester form can increase pyrazine formation while reducing amine formation, thereby reducing the intensity of fishy odor in crustacean-based products [51]. Thus, the frying process produces relatively similar volatile profiles between treatments, resulting in no significant differences in odor.

### 3.7.3. Texture

The Kruskal Wallis test results showed that the substitution of mole crab flour had a significant effect ( $p < 0.05$ ) on the hedonic score of cassava-based *lanting* texture compared to P0 (Figure 7). Panelist preference scores increased to an optimum point at P2, then decreased at higher concentrations. At P2, the product had a crispier and more brittle texture, while high concentrations produced a denser and harder texture, thus decreasing panelist acceptance. This finding is consistent with a study of coconut dregs cake substituted with vannamei shrimp head flour, where the hedonic score of texture increased from 3.36 (control) to 4.28 at 10% substitution, then decreased to 2.96 at 15% substitution [59]. A similar trend was found in croissants with shrimp shell flour substitution, where the highest acceptance was obtained at 2.5% substitution with a score of 7.10 and decreased to 6.70 at 5% and 6.00 at 7.5% [50].

Mechanistically, texture changes are influenced by starch gelatinization, starch–protein–water interactions, and the presence of chitin in the food system. Gelatinization occurs when starch granules absorb water during heating, disrupting their crystalline structure and forming a gel network as the basis of the product structure [60]. Animal protein interacts with starch and water to form a denser matrix that inhibits starch granule expansion, characterized by an increase in the initial gelatinization temperature [61]. Chitin, as a structural polysaccharide, has a lower water-binding capacity than starch; therefore, at high concentrations, it acts as a filler that reduces free water and limits starch granule expansion, resulting in a denser and more rigid matrix [62]. Other research showed that increasing the frying temperature to 180 °C correlated with a decrease in the average water content to approximately 3.78%, accompanied by a decrease

in bulk density to  $0.21 \text{ g/cm}^3$  and an increase in linear expansion to 95.2% in fish crackers made from tapioca flour and carp (*Cyprinus carpio*) meat, which reflected a crispier and lighter texture. Thus, the interaction of starch gelatinization, starch-protein matrix formation, and the presence of chitin are the main factors that determine product texture and the level of panelist acceptance [63].

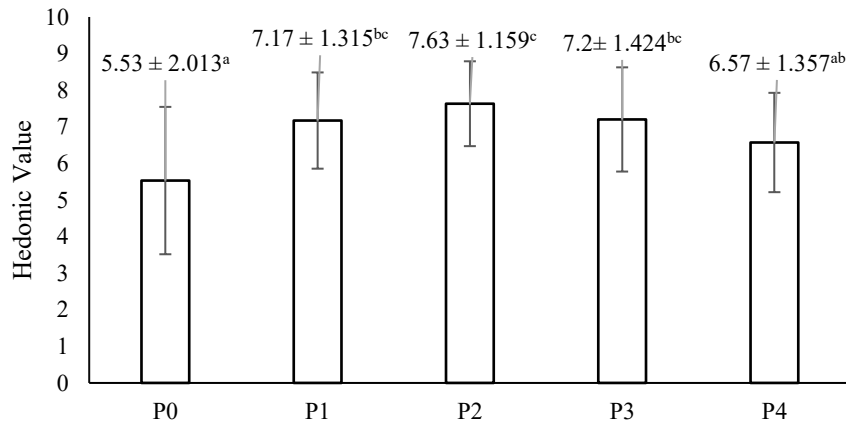


Figure 7. Mean texture ratings for *lanting*. Superscript letters that differ represent statistically meaningful variation ( $p < 0.05$ ).

### 3.7.4. Taste

The Kruskal Wallis test results showed that the substitution of mole crab flour had a significant effect ( $p < 0.05$ ) on the hedonic taste score of *lanting* compared to the control (P0) (Figure 8). Panelist acceptance increased to an optimum point at P2, then decreased at higher concentrations. At P2, a savory balance was formed between the neutral characteristics of cassava and the distinctive crustacean flavor, while higher concentrations produced a fishy and slightly bitter taste that decreased panelist acceptance. This finding is in line with a study of coconut dregs cake substituted with whiteleg shrimp head flour, where the hedonic taste score increased from 3.50 (P0) to a maximum of 4.60 at a substitution of 10 g (P2), then decreased to 2.08 at a substitution of 15 g (P3) [59].

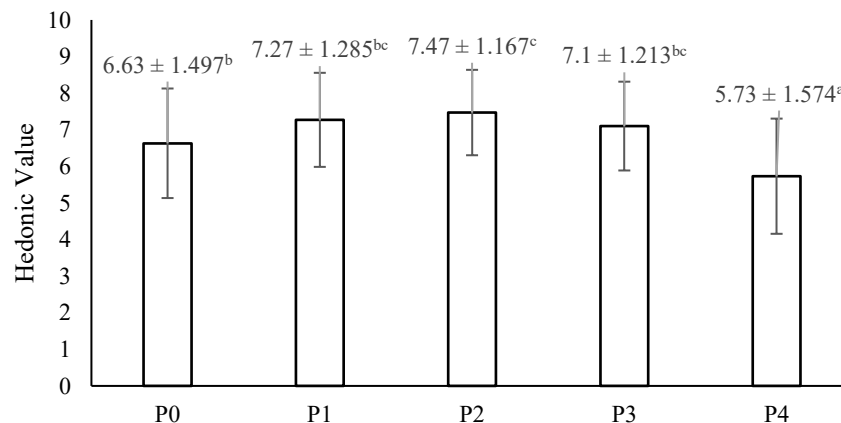


Figure 8. Mean taste ratings for *lanting*. Variations in superscript letters represent statistically meaningful differences between treatments ( $p < 0.05$ ).

Mechanistically, flavor formation is influenced by non-volatile and volatile compounds in crustacean-based ingredients. Free amino acids such as glutamate and aspartate contribute to the umami taste, while glycine and alanine provide a sweet impression that enriches the taste of the product, while

sodium ions strengthen the perception of savory taste through synergistic interactions with amino acids [64]. Flavor intensity is influenced by the taste activity value (TAV), where compounds with a TAV>1 contribute significantly to the product's flavor [65]. However, at high concentrations, TMA formed from the degradation of TMAO during heating, can dominate and produce a fishy taste and aroma [66]. Partial protein hydrolysis during processing can also produce hydrophobic peptides that induce bitterness, although the addition of sulfur-containing precursors such as cysteine in the maillard reaction has been reported to help reduce this bitterness [67]. On the other hand, the maillard reaction during frying produces heterocyclic compounds such as pyrazines, furans, and sulfur compounds that enhance the savory and meaty flavor characteristics [68]. Thus, the balance between the concentration of flavor-active compounds and their sensory thresholds is a key factor in determining panelists acceptance of a product.

### 3.7.5. Determination of the Best Treatment

The determination of the best treatment in this study employed the Exponential Comparison Method (ECM) as a component of a decision support system. Each criterion was assigned a weight according to its relative level of importance, after which the value of each alternative was calculated using an exponential formula to generate a total decision score. The alternative with the highest total score was designated as the primary choice. This approach is considered effective as it is capable of producing objective, consistent, and measurable rankings in the process of selecting the best alternative [69].

Table 4. Determination of the best treatment for *lanting*.

Parameter	Weight	Component Alternative Score									
		P0		P1		P2		P3		P4	
		Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Moisture	7%	5	0.35	2	0.14	3	0.21	4	0.28	1	0.07
Ash	6%	5	0.30	4	0.24	3	0.18	2	0.12	1	0.06
Fat	7%	4	0.28	3	0.21	5	0.35	1	0.07	2	0.14
Protein	8%	5	0.40	4	0.32	3	0.24	1	0.08	2	0.16
Carbohydrate	7%	4	0.28	3	0.21	5	0.35	1	0.07	2	0.14
Calcium	25%	5	1.25	4	1.00	1	0.25	2	0.50	3	0.75
Appearance	9%	4	0.36	3	0.27	1	0.09	2	0.18	5	0.45
Odor	9%	4	0.36	3	0.27	1	0.09	2	0.18	5	0.45
Texture	10%	5	0.50	3	0.30	1	0.10	2	0.20	4	0.40
Taste	12%	4	0.48	2	0.24	1	0.12	3	0.36	5	0.60
Total Score	100%	4.56		3.20		1.98		2.04		3.22	
Rank		5		3		1		2		4	

Note: Selection of the optimal *lanting* treatment relied on the highest cumulative score obtained from organoleptic and chemical analyses.

Based on the ECM calculation presented in Table 4, the best treatment was determined by considering chemical parameters including moisture content, ash, fat, protein, carbohydrate, and calcium, as well as sensory parameters encompassing appearance, odor, texture, and taste. The calcium parameter was assigned the highest weight as the primary focus of the study, while sensory parameters received high weights to ensure adequate consumer acceptability. The analysis revealed that treatment P2 yielded the lowest total preference value of 1.98, establishing it as the most optimal formulation among all treatments.

The primary advantage of P2 lies in its calcium content of 768.33 mg/100 g, which is sufficiently adequate to meet daily requirements without exceeding safe consumption limits. Although the fat and carbohydrate content of P2 did not rank highest among all treatments, both parameters met the established eligibility criteria for food products. From a sensory perspective, panelists rated P2 more favorably than higher substitution treatments, as excessive addition of mole crab flour tended to cause the fishy flavor and odor characteristic of seafood to become overly dominant, thereby reducing consumer appeal.

Consequently, P2 was selected as the optimal formulation, capable of maximizing nutritional value while maintaining consumer acceptability.

### 3.7.6. Nutritional Information

The nutritional value of cassava *lanting* with P2 treatment of mole crab flour substitution, which was determined as the best treatment, was evaluated based on proximate composition and calcium content analysis. Nutritional characteristics of the product are summarized in Table 5. Cassava *lanting* with mole crab flour substitution at treatment P2 yielded an energy content of 130 kcal per 25 g serving, comprising 7 g fat, 1 g protein, 14 g carbohydrate, 180 mg sodium, and 192.08 mg calcium. Fat constituted the dominant fraction at approximately 28% of serving weight, while protein remained relatively low. The carbohydrate content of the product was determined using the by difference method based on the measured moisture, ash, protein, and fat contents. Since sugar content was not directly analyzed in this study, no conclusions regarding the number of sugars in the product can be drawn. Calcium content reached approximately 15% of the daily value per serving, surpassing other tuber-based snacks, attributable to the mineral-rich characteristics of mole crab flour, with calcium content of 26.52 mg/g in the flour increasing to 28.85 mg/g following processing [8].

Table 5. Daily nutritional contribution for adolescents (10–18 years) based on the consumption of *lanting* products.

NUTRITION INFORMATION		
Serving size: 25 g		
Servings per package: 4		
AMOUNT PER SERVING		
<b>Total Energy</b>		<b>130 kkal</b>
		<b>%RDA*</b>
<b>Total Fat</b>	7 g	11%
<b>Protein</b>	1 g	2%
<b>Total Carbohydrate</b>	14 g	4%
<b>Sodium</b>	180 mg	12%
<b>Calcium</b>	192,08 mg	15%
*Percent recommended dietary allowance based on an energy intake of 2,150 kcal.		

Scientifically, this nutritional profile indicates that P2 has potential as a calcium source to support bone health and reduce the risk of osteoporosis. However, the fat content of 7 g per serving reflects the typical characteristics of fried starch-based products, in which moderate consumption as a snack (1–2 servings per day) does not directly increase the risk of metabolic diseases in healthy individuals. Nevertheless, chronic excessive consumption of high-fat products has been associated with an increased risk of cardiovascular and metabolic diseases in long-term prospective studies [70]. The sodium content of 180 mg per serving remains within a moderate range. However, consumption of one full package (100 g) would provide approximately 720 mg of sodium, which should be taken into consideration, particularly for individuals with a history of hypertension. Consumers are therefore advised to monitor their total daily sodium intake from various food sources in accordance with the World Health Organization (WHO) recommendation that sodium intake should not exceed 2,000 mg per day [71].

## 4. CONCLUSION

This study demonstrated that substitution of mole crab flour in cassava-based *lanting* significantly increased the calcium, protein, and ash contents of the product as the substitution proportion increased, while formulation P2 was identified as the best treatment because it successfully balanced nutritional enhancement with optimal sensory acceptance in terms of appearance, texture, and taste. Nevertheless, this

study has several limitations, as it only evaluated proximate composition and calcium content without assessing calcium bioavailability through in vitro or in vivo approaches, did not comprehensively examine other minerals such as phosphorus and magnesium, and did not analyze product shelf life or oxidative stability during storage. Therefore, further studies are recommended to explore calcium bioavailability, amino acid and fatty acid profiles, as well as product shelf-life evaluation in order to support the development of sustainable local wisdom-based functional foods.

#### AUTHOR CONTRIBUTION

All author contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Kharisma Feri Setiawan**: preparing the initial draft, conducting the formal analysis, and revising the manuscript, and acted as the lead author overseeing the preparation and refinement of the article. **Rifki Prayoga Aditia** and **Devi Faustine Elvina Nuryadin**: reviewing and improving the manuscript.

#### CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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