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ORIGINAL ARTICLE

# Product Quality and Economic Evaluation of Spicy-Filled Meatballs from Green Mussel (*Perna viridis*)

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**ABSTRACT**

Green mussel (*Perna viridis*) has potential for diversification into value-added fishery products. This study evaluated the production flow, sensory quality, preliminary storage observation, economic feasibility, and value added of green mussel-filled meatballs. The product was prepared using 200 g of green mussel meat as a spicy filling and evaluated using sensory testing, descriptive storage observations, business feasibility indicators, and the Hayami value-added method. Sensory scores ranged from 8.0 to 8.5, with all attributes exceeding the minimum requirement of SNI 7266:2017. During preliminary storage observations over 6 days, frozen samples remained relatively unchanged, whereas samples stored at room temperature and under hot/sun-exposed conditions showed visible and sensory deterioration within approximately 2–3 days. Production of 15 cups generated IDR 150,000 in revenue from a recorded cost of IDR 119,650, resulting in an operating surplus of IDR 30,350, an R/C ratio of 1.25, and a break-even point of approximately 5 cups. Hayami analysis generated IDR 151,750 1/kg of green mussel in value added, with a 20.23 % value-added ratio, classified as moderate. These findings indicate that green mussel-filled meatballs have promising sensory characteristics and positive economic potential as a diversified fishery product.

## 1 INTRODUCTION

Green mussel (*Perna viridis*) is a commercially important bivalve with considerable potential for further development as a raw material for diversified fishery products (Manurung et al. 2026). In Indonesia, green mussels are relatively accessible and can provide an affordable source of animal protein for coastal and urban communities. Nutritionally, green mussel meat contains approximately 7.14–13.1 % protein, 1.06–1.97 % lipid, 0.84–3.78 % soluble carbohydrate, 0.99–1.42 % crude ash, and is rich in essential amino acids and minerals, while the edible meat accounts for approximately 30 % of the whole mussel weight (Chakraborty & Joseph 2015; Nuñal et al. 2023). However, their high perishability and the relatively low value of minimally processed products highlight the importance of appropriate processing and product diversification. Developing convenient processed foods may broaden their utilization, improve market opportunities, and increase the economic value generated from this fishery resource (Basri & Rizki 2023).

Previous studies have explored the use of green mussels in various processed foods, including kamaboko (Basri & Rizki 2023), fortified pudding (Anggraini et al. 2024), nuggets (Rohmat et al. 2024), sambal (Lestari et al. 2022), noodles (Sorio & Arcales 2022), and seasoning products (Kingwascharapong et al. 2024). Collectively, these studies indicate that green mussels can be successfully incorporated into various processed foods. However, product development should not be evaluated solely from the perspective of technological feasibility or nutritional composition. Consumer acceptance, sensory attributes (texture, taste, and overall liking), and the economic value created through processing are equally important determinants of whether a diversified product, such as green mussel meatballs, can be sustainably commercialized.

Meatballs provide a familiar and convenient format for developing value-added fishery products (Dewi et al. 2024). Previous research on catfish meatballs has demonstrated that processing can generate additional economic value, although the magnitude depends on factors such as output value and input costs (Gumilar et al. 2021). For green mussel-filled meatballs, sensory evaluation and production-cost analysis are important for

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assessing product acceptability and preliminary economic potential. Descriptive storage observations can also provide initial information about visible and sensory changes under specified storage conditions, although they cannot establish a validated shelf life or confirm microbiological safety.

Despite the development of various green mussel-based foods, an integrated assessment of sensory quality, preliminary storage characteristics, and production economics for spicy-filled green mussel meatballs remains limited. This gap is relevant because product diversification should be assessed in terms of both product quality and the economic value generated from the raw material. Therefore, this study aimed to describe the production process, evaluate the sensory quality of spicy-filled green mussel meatballs, document observable changes during storage under the tested conditions, and assess production feasibility and value added using recorded production data. It was expected that the product would demonstrate acceptable sensory characteristics and positive preliminary economic potential. The storage observations were intended to provide descriptive evidence of product changes rather than a validated determination of shelf life, while the economic analysis was intended to characterize the recorded production batch rather than establish comprehensive commercial profitability.

## 2 MATERIALS AND METHODS

### 2.1 Study design and production site

This study was conducted at the Teaching Factory of the Marine and Fisheries Polytechnic of Jembrana, Bali, Indonesia, using a descriptive quantitative design. The study focused on the production process, sensory quality, preliminary storage observations, production costs, and economic value added of spicy-filled meatballs made from green mussel (*Perna viridis*).

The product was prepared in one production batch using the standardized formulation described in Section 2.2. The batch yielded 15 cups, with five meatballs packed in each 500 mL cup. This batch served as the basis for the production records and the subsequent production cost, revenue, economic-feasibility, and value-added analyses. No independent production-batch repetitions were conducted; therefore, the economic results represent a single-batch assessment rather than an estimate of average performance across repeated production cycles.

### 2.2 Product formulation and processing

The principal raw material was shelled green mussel meat. For the standardized economic batch, 200 g mussel meat, 250 g wheat flour, and 200 g tapioca flour were used together with garlic powder, pepper, seasoning, salt, chili, and other serving ingredients. The process consisted of raw-material preparation and washing, seasoning and cooking the mussel filling, mixing the meatball dough, forming balls with spicy mussel filling, boiling until cooked, draining, broth preparation, portioning, and packaging. Each 500 mL cup contained five meatballs, one tofu portion, noodles, broth, sauce, sweet soy sauce, chili powder, and crunchy topping.

### 2.3 Sensory evaluation and storage observation

Consumer evaluation involved 30 untrained panelists based on SNI 7266:2017 concerning fish meatballs (BSN 2017). The results were calculated following SNI 2346:2011 concerning guidelines for organoleptic and/or sensory testing on fishery products (BSN 2011). The panelists were aged 18–30 years and comprised 16 females (53.33 %) and 14 males (46.67 %), including students and employees. Four sensory attributes were evaluated, namely appearance, odor, taste, and texture, using a three-level scoring scale of 5, 7, and 9, with higher scores indicating better sensory quality. Appearance scores ranged from 5 (rough, porous, and dull) to 9 (smooth, bright, and non-porous), with 7 indicating a relatively smooth, slightly porous, and moderately bright surface. Odor was scored as 5 (neutral), 7 (somewhat product-specific), or 9 (product-specific). Texture scores ranged from 5 (non-firm, non-compact, and non-chewy) to 9 (firm, compact, and chewy), with 7 indicating a firm and compact texture with moderate chewiness. Sensory data were analyzed descriptively to summarize the panelists' assessments of appearance, odor, taste, and texture. The resulting scores were calculated according to the sensory evaluation procedure described in SNI 2346:2011 and compared with the minimum sensory quality criterion of 7. No inferential statistical tests were performed; therefore, the results are presented as descriptive findings rather than evidence of statistically significant differences.

A preliminary storage observation was conducted over 6 days under three storage conditions: frozen storage at −18 °C, room-temperature storage at 23–25 °C, and hot/sun-exposed storage at temperatures above 27 °C. Eighteen polyethylene plastic bags were prepared, with six bags assigned to each storage condition. Each bag contained one meatball and served as an individual sample. One previously unopened bag was opened and examined daily for each storage condition to observe changes in product appearance, odor, texture, and visible signs of deterioration, including mold growth. After inspection, the opened sample was discarded and was not returned to storage. Thus, separate samples were used for each daily observation to avoid repeated opening and handling of the same package. The observations were analyzed descriptively to characterize changes in product quality under the different storage

conditions. No microbiological testing or validated shelf-life determination was conducted; therefore, the findings should not be interpreted as confirmation of microbiological safety or as a validated estimate of product shelf life.

### 2.4 Economic Feasibility

Economic feasibility was analyzed based on the cost and revenue structure of spicy-filled meatballs production. Production costs were classified into fixed costs ($FC$) and variable costs ($VC$), where total production cost ($TC$) was calculated as:

$$TC = FC + VC \tag{1}$$

The cost of production per unit ($CPU$) was determined by dividing the total production cost by the quantity of product produced:

$$CPU = \frac{TC}{Q} \tag{2}$$

where $Q$ is the number of cups produced. The selling price ($P$) was established by adding the targeted profit margin to the production cost per unit. Total revenue ($TR$) was calculated from the quantity of products sold multiplied by the selling price, while net operating income ($NI$) was calculated as the difference between total revenue and total production cost:

$$TR = Q \times P \tag{3}$$

$$NI = TR - TC \tag{4}$$

Business feasibility was further evaluated using the Revenue-Cost Ratio (R/C ratio) and Break-Even Point (BEP). The R/C ratio was calculated by comparing total revenue with total production cost:

$$R/C = \frac{TR}{TC} \tag{5}$$

An R/C ratio greater than 1 indicates that the business generates revenue exceeding its production costs and is therefore economically feasible; $R/C = 1$ represents the break-even condition; and $R/C < 1$ indicates that the business is not economically feasible. This interpretation is also the criterion used in the original Bomerang report. The BEP was used to determine the minimum production or sales volume required for total revenue to cover production costs and was calculated as:

$$BEP_{unit} = \frac{FC}{P - VC_u} \tag{6}$$

where $VC_u$ is the variable cost per unit.

### 2.5 Value–Added Analysis

Value-added analysis was conducted using an adapted version of the Hayami method (Hayami et al. 1987) to estimate the additional economic value generated by processing green mussel into spicy-filled meatballs. The method was adapted to the available production records and the objectives of this study in two respects. First, because the final product was recorded as saleable cups rather than by weight, the conversion factor and output value were calculated using the number of cups produced per kilogram of green mussel raw material. Second, labor-related variables, including labor input, labor coefficient, average wage, labor income, and labor share, were not recorded in the original production data. Value added was therefore calculated by subtracting the raw-material cost and other recorded input costs from the output value per kilogram of green mussel. The value-added ratio was calculated as value added divided by output value, multiplied by 100. The processing margin and its distribution between other input contributions and value added were also calculated. Accordingly, the analysis represents an adapted application of the Hayami framework rather than a complete implementation of all conventional Hayami components. Labor-related omissions should be considered when interpreting the results, and value added should not be interpreted as net profit. The variables and equations used for the value-added analysis are presented in Table 1.

## 3 RESULTS AND DISCUSSION

### 3.1 Product characteristics and processing

The production of green mussel meatballs was carried out through sequential stages as illustrated in Figure 1. Green mussels were initially sorted to remove unsuitable materials, followed by washing and cleaning to eliminate visible dirt and adhering impurities. The edible mussel meat was then separated from the shells for further processing. Careful handling at this stage is particularly important for bivalve molluscs because they are filter-feeding organisms capable of accumulating microorganisms and other contaminants from their growing environment. FAO and WHO therefore recommend appropriate sourcing, sorting, washing, hygienic handling, and, where required, validated depuration procedures for bivalve molluscs (FAO & WHO 2012; Lee et al. 2008). Sorio & Arcales (2022) similarly emphasized appropriate handling and depuration in green mussel processing and identified product diversification as an approach for improving the utilization and economic value of this resource.

The meatball dough was prepared separately from wheat flour, tapioca flour, garlic, pepper, salt, seasoning, water, and ice. The dough was mixed until homogeneous,

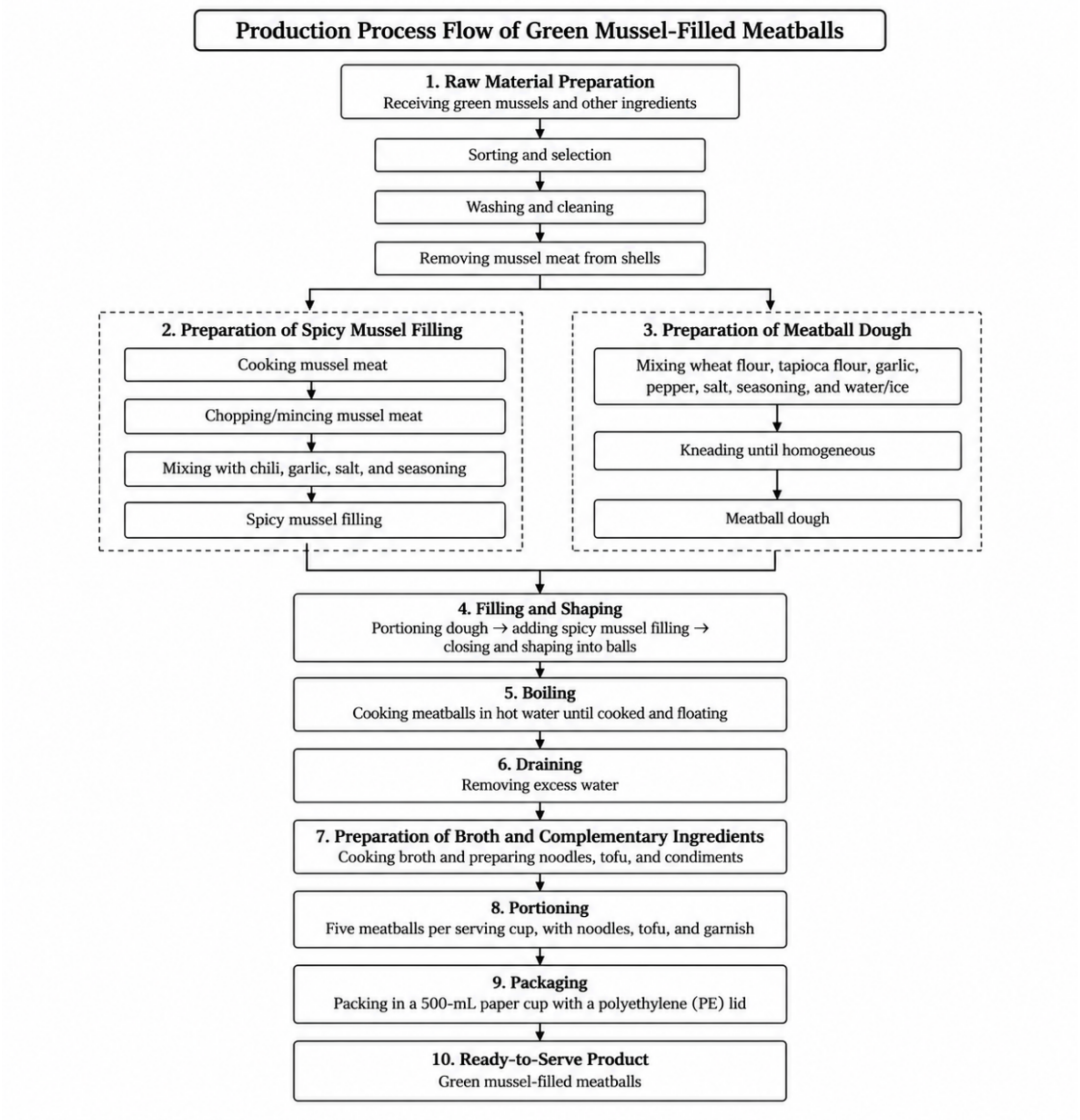



**Figure 1.** Production Flow of Green Mussel Meatballs.

portioned, filled with the spicy mussel mixture, and shaped into balls. Starch is important for forming the outer structure because it functions as a filler, increases water-holding capacity, and contributes to firmness and gel strength during heating (Huang et al. 2024; Meng et al. 2022). Tee & Siow (2017) similarly found that increasing tapioca starch concentration in fish balls increased water-holding capacity, gel strength, hardness, springiness, cohesiveness, and chewiness. These mechanisms support the use of wheat and tapioca flours as the structural matrix surrounding the mussel filling.

The shaped meatballs were boiled until cooked and floating, and subsequently drained. Heating is a critical structure-forming stage because starch gelatinization occurs simultaneously with changes in the protein-containing food matrix, increasing rigidity and producing a stable cooked structure. Boiling also influences moisture transfer, nutrient retention, and the final texture of meatball-type products (Feng et al. 2017). After draining, five meatballs were portioned with noodles and tofu, accompanied by broth and condiments, and packed in 500 mL PE-coated paper cups. Overall, the process provides a relatively simple approach for converting green mussel meat into a spicy filling within a starch-based meatball matrix, thereby diversifying its utilization without directly incorporating the mussel into the dough.

### 3.2 Consumer sensory acceptance

The sensory evaluation showed that the green mussel-filled meatballs achieved high scores for all attributes, with aroma and taste receiving the highest scores (8.5), followed by appearance and texture (8.0). All scores exceeded the minimum sensory quality criterion of 7 specified in SNI 7266:2017, indicating that the

**Table 1.** Value-Added Analysis framework for Green Mussel Meatballs.

| No. | Variable | Formula |
|---|---|---|
| **I. Output, Input, and Price** | | |
| 1 | Output (cup/production batch) | $A$ |
| 2 | Green mussel input (kg/production batch) | $B$ |
| 3 | Conversion factor (cup/kg green mussel) | $D = A/B$ |
| 4 | Output price (IDR/cup) | $F$ |
| **II. Value Added** | | |
| 5 | Green mussel price (IDR/kg) | $H$ |
| 6 | Other input contribution (IDR/kg green mussel) | $I$ |
| 7 | Output value (IDR/kg green mussel) | $J = D \times F$ |
| 8 | Value added (IDR/kg green mussel) | $K = J - H - I$ |
| 9 | Value-added ratio (%) | $L = K/J \times 100$ |
| **III. Margin Distribution** | | |
| 10 | Processing margin (IDR/kg green mussel) | $Q = J - H$ |
| a | Other-input share (%) | $S = I/Q \times 100$ |
| b | Value-added share (%) | $T = K/Q \times 100$ |

**Note:** The Hayami method was adapted to express output as saleable cups per kilogram of green mussel raw material because the final product weight was not recorded. Labor-related variables were excluded because labor input and wage data were unavailable. Therefore, the analysis estimates value added based on the recorded inputs and should not be interpreted as a complete measure of net profit.

product met the sensory quality requirement presented in Table 2. The results were analyzed descriptively based on assessments from 30 untrained panelists, without inferential statistical tests; therefore, the scores represent the panelists' sensory assessments rather than statistically significant differences among attributes.

Green mussel naturally has a characteristic fishy aroma, while processing and seasoning can modify its sensory profile. Fitriah et al. (2018) similarly described fresh green mussel meat as having a characteristic fishy odor and elastic texture. The high aroma and taste scores suggest that the characteristic flavor of green mussel, together with chili, garlic, salt, and other seasonings used in the filling, was well accepted by the panelists. This agrees with previous studies showing that processed green mussel products can retain favorable sensory characteristics after thermal processing (Biji et al. 2015). Rajasekaran et al. (2021) added that the heating process retains valuable nutrients in green mussel meat. In thermally processed *Perna viridis*, sensory scores remained acceptable, with reported values of approximately 7.5 for taste and odor and 8.0 for firmness. A recent study on seasoned green mussels also evaluated color, taste, flavor, texture, and overall acceptance as key determinants of consumer acceptability, confirming the importance of flavor-related attributes in green mussel products (Kingwascharapong et al. 2024).

The slightly lower scores for appearance and texture (8.0) may be related to the structural characteristics of

**Table 2.** Sensory evaluation results compared to the SNI 7266:2017 standard.

| Parameter | Interval | Sensory Value | SNI 7266:2017 |
|---|---|---|---|
| Appearance | $8.23 \leq 8.53$ | 8 | Min. 7 |
| Aroma | $8.53 \leq 8.80$ | 8.5 | |
| Taste | $8.50 \leq 8.73$ | 8.5 | |
| Texture | $8.31 \leq 8.60$ | 8 | |

**Note:** The calculation is in accordance with SNI 2346:2011 concerning guidelines for organoleptic and/or sensory testing on fishery products.

the flour-based outer dough and the effect of cooking. In meatball systems, tapioca starch acts as a filler and water binder and contributes to compactness, elasticity, and chewiness through starch gelatinization during heating (Khotimah et al. 2024). Similar findings were reported for threadfin bream meatballs, where flour formulation significantly affected sensory and physical characteristics; the selected formulation obtained sensory scores of 7.62 for appearance, 7.75 for aroma, 8.00 for taste, and 7.83 for texture (Fadhallah et al. 2024). These results are comparable with the present study and indicate that the combination of a starch-based dough and seasoned green mussel filling can produce a sensory-acceptable product.

### 3.3 Preliminary storage observation

The descriptive observations showed a clear temperature-dependent deterioration pattern in green mussel-filled meatballs during 6 days of storage (Table 3). Under frozen storage, the product stored at −18 °C remained relatively unchanged throughout the observation period, maintaining a hard texture, white appearance, and characteristic aroma from Day 1 to Day 6. In contrast, samples stored at room temperature (23–25 °C) deteriorated rapidly. The product was still normal on Day 1, but softening and off-odor were already observed on Day 2, followed by visible mold growth and spoiled odor from Day 3 onward. Mold development became progressively more extensive, changing from initial growth to white mold and finally dark mold by Day 6. Samples exposed to hot/sun conditions (> 27 °C) also showed progressive quality loss. Although they remained chewy during the first 2 days, softening and unpleasant odor became apparent on Day 3, followed by putrid odor, increasingly soft texture, and whitish-brown discoloration on Days 4–6. Overall, frozen storage provided the greatest short-term stability, whereas room-temperature and hot/sun-exposed conditions caused substantial deterioration within approximately 2–3 days. However, because the assessment relied on descriptive observations of appearance, odor, and texture without microbiological or physicochemical analyses, the results do not establish a validated shelf life or confirm product safety.

**Table 3.** Descriptive changes in green mussel-filled meatballs during preliminary storage observations under different conditions.

| Day | Frozen (−18 °C) | Room temperature (23–25 °C) | Hot/sun-exposed (> 27 °C) |
|---|---|---|---|
| 1 | Hard; white; characteristic aroma | Normal texture; white; no spoiled odor | Chewy; normal brown; normal odor |
| 2 | Hard; white; characteristic aroma | Soft; off-odor begins | Chewy; stronger odor |
| 3 | Hard; white; characteristic aroma | Soft; mold begins; spoiled odor | Slightly soft; unpleasant odor |
| 4 | Hard; white; characteristic aroma | Soft; white mold; spoiled odor | Slightly soft; putrid odor |
| 5 | Hard; white; characteristic aroma | Soft; extensive white mold; spoiled odor | Very soft; putrid odor; whitish-brown |
| 6 | Hard; white; characteristic aroma | Soft; dark mold; spoiled odor | Extremely soft; strongly putrid; whitish-brown |

These findings are consistent with the fundamental effect of temperature on seafood spoilage. According to FAO, temperature is one of the most important factors controlling both microbial proliferation and enzymatic deterioration in fish and shellfish products; microbial growth generally accelerates as storage temperature increases, whereas low-temperature storage markedly slows spoilage processes (FAO & WHO 2012; Huss 1995). This explains why the frozen samples retained their original sensory characteristics while the other treatments deteriorated rapidly. The development of off-odors can be associated with microbial and biochemical degradation of nitrogenous compounds, whereas softening may result from structural breakdown of proteins and other tissue components during storage. Visible mold growth in the room-temperature samples further indicates advanced spoilage and confirms that the product was no longer sensorially acceptable. Similar trends have been reported for *Perna viridis*, where a chilled-storage study found progressive increases in TVB-N, TMA-N, pH, ammonia, and microbial counts during storage, while sensory quality declined; untreated green mussels remained acceptable for only about 6 days under chilled conditions, although pretreatments extended this period (Arcales & Nacional 2019).

### 3.4 Cost structure and business feasibility

The production of green mussel-filled meatballs required a total recorded cost of IDR 119,650 per batch, with an output of 15 cups (Table 4). Variable costs accounted for IDR 105,650 (88.3 %), while allocated gas and transportation costs contributed IDR 14,000 (11.7 %) of the total production cost. The resulting production cost was approximately IDR 7,977 per cup. At a selling price of IDR 10,000 per cup, one production batch generated IDR 150,000 in revenue and an operating surplus of IDR 30,350, equivalent to approximately IDR 2,023 per cup or 20.23 % of sales revenue. These results indicate that the selling price was sufficient to recover the recorded production expenditure and provide a positive operating return. However, the relatively high proportion of variable costs indicates that profitability is particularly sensitive to changes in ingredient, packaging, and complementary-material prices.

The revenue-to-cost (R/C) ratio was 1.25, indicating that every IDR 1.00 of recorded production cost generated approximately IDR 1.25 in sales revenue. An R/C ratio greater than 1 indicates that revenue exceeds production costs and is generally interpreted as an economically feasible or efficient production activity (Ngamel 2015; Saputro et al. 2018). The feasibility of the green mussel-filled meatballs was further supported by the break-even analysis. The resulting break-even point was 4.73 cups, or approximately 5 cups per batch, which was substantially lower than the actual production and sales volume of 15 cups. Thus, production operated above the calculated break-even level and generated a positive operating surplus. BEP represents the minimum production or sales level at which total revenue is sufficient to cover the relevant costs, whereas the R/C ratio describes the efficiency of revenue generation relative to production costs. Similar use of R/C and BEP as complementary business-feasibility indicators has also been reported in Indonesian agroindustry studies (Saputro et al. 2018).

Nevertheless, these findings should be interpreted as a preliminary assessment of operational feasibility rather than a complete investment-feasibility analysis. Although the R/C ratio of 1.25 indicates a positive economic return under the recorded cost structure, its relatively modest margin above the feasibility threshold ($R/C = 1$) suggests that the business may be sensitive to increases in input prices or additional operating expenses. More comprehensive feasibility studies commonly incorporate additional financial indicators and a broader accounting of production and investment costs. In the present study, labor remuneration, equipment depreciation, facility costs, utilities, marketing expenses, product losses, taxes, and other overheads were not comprehensively documented. Their inclusion could increase the actual production cost and consequently reduce the operating surplus and R/C ratio. Therefore, the current results demonstrate positive economic potential at the experimental batch scale, while assessment of commercial-scale feasibility would require more complete cost accounting, repeated production cycles, and preferably sensitivity analysis to evaluate

**Table 4.** Cost structure and business feasibility of green mussel-filled meatballs per production batch.

| Economic indicator | Value | Interpretation |
|---|---|---|
| Production volume | 15 cups/batch | Batch output |
| Variable cost | IDR 105,650 | 88.3 % of total recorded cost |
| Allocated cost | IDR 14,000 | 11.7 % of total recorded cost |
| **Total production cost** | **IDR 119,650** | **IDR 7,977/cup** |
| Selling price | IDR 10,000/cup | Actual selling price |
| **Revenue** | **IDR 150,000/batch** | 15 cups × IDR 10,000 |
| **Operating surplus** | **IDR 30,350/batch** | **Revenue – recorded cost** |
| Operating surplus/cup | IDR 2,023 | Based on 15 cups |
| Operating surplus margin | 20.23 % | Surplus/revenue ×100 |
| **R/C ratio** | **1.25** | **Revenue exceeds recorded cost** |
| Variable cost/cup | IDR 7,043 | Used for BEP calculation |
| Contribution margin/cup | IDR 2,957 | Price – variable cost/cup |
| **BEP production** | **≈ 5 cups** | **Below actual output of 15 cups** |

the effects of changes in raw-material prices, production volume, and selling price.

### 3.5 Value-added analysis

The Hayami analysis showed that processing green mussel meat into green mussel-filled meatballs generated an added value of IDR 151,750 1/kg of green mussel, corresponding to a value-added ratio of 20.23 % (Table 5). The production process used 200 g of green mussel meat to produce 15 cups, resulting in a conversion factor of 75 cups per kg and an output value of IDR 750,000 1/kg of green mussel. After deducting the green mussel raw-material cost of IDR 45,000 1/kg and other input contributions of IDR 533,250 1/kg, the resulting value added was IDR 151,750 1/kg. The processing margin was IDR 705,000 1/kg, of which 78.48 % was attributable to other input contributions and 21.52 % represented the value-added share. Based on the classification applied by Gumilar et al. (2021), in which value-added ratios of $< 15$ %, 15–40 %, and $> 40$ % are categorized as low, moderate, and high, respectively, the 20.23 % value-added ratio was classified as moderate. These results indicate that processing green mussels into a ready-to-serve product generated additional economic value. However, value added should not be interpreted as net profit because labor costs were not recorded separately. Accordingly, the value-added ratio represents the proportion of output value attributable to value added under the adapted Hayami calculation, rather than a profit rate. The results should therefore be interpreted as an assessment of value creation based on the available production records, not as a complete measure of business profitability.

The 20.23 % value-added ratio was higher than the 13 % reported by Gumilar et al. (2021) for catfish meatballs, which generated value added of IDR 19,600 1/kg, indicating a greater proportional increase in economic value in the present product. In contrast, the present value-added ratio was lower than the 27.38 % reported for mackerel tuna processed into keumamah and the 40.01 % reported for tuna floss processing by Qamarani et al. (2026). These comparisons indicate that the magnitude of value added in fishery processing depends not only on the selling value of the final product but also on the efficiency with which raw materials are converted into marketable output and the cost of additional inputs required during processing. Thus, the moderate value-added ratio obtained for green mussel-filled meatballs demonstrates positive economic value creation while highlighting non-mussel input costs as an important area for improving processing efficiency and value capture.

## 4 CONCLUSION

Green mussel meat can be successfully diversified into spicy-filled meatballs with favorable sensory quality and positive economic potential. All sensory attributes met the applicable SNI requirements, while frozen storage maintained the product's descriptive quality throughout the 6 days observation period, in contrast to rapid deterioration under room-temperature and hot/sun-exposed conditions. At the experimental batch scale, production was operationally feasible, with an R/C ratio of 1.25, a BEP of approximately 5 cups, and a positive operating surplus. The Hayami analysis further demonstrated a moderate value-added ratio of 20.23 %, equivalent to IDR 151,750 1/kg of green mussel. Overall, the results support green mussel-filled meatballs as a potential value-added fishery product. Nevertheless, further studies incorporating microbiological and physicochemical analyses at defined storage intervals, complete cost accounting, and larger production scales are needed to establish product shelf life and safety and to confirm commercial feasibility.

**Table 5.** Value-added analysis of green mussel-filled meatballs.

| No. | Variable | Result |
|---|---|---|
| **Output, Input, and Price** | | |
| 1 | Output | 15 cups/batch |
| 2 | Green mussel input | 0.2 kg/batch |
| 3 | Labor input* | Not recorded |
| **4** | **Conversion factor** | **75 cups/kg** |
| 5 | Labor coefficient* | Not calculated |
| 6 | Output price | IDR 10,000/cup |
| 7 | Average labor wage | Not recorded |
| **Income and Value Added** | | |
| 8 | Green mussel price | IDR 45,000/kg |
| 9 | Other input contribution | **IDR 533,250/kg** |
| **10** | **Output value** | **IDR 750,000/kg** |
| **11** | **Value added** | **IDR 151,750/kg** |
| | **Value-added ratio** | **20.23 %** |
| 12 | Labor income | Not calculated |
| | Labor share | Not calculated |
| **13** | **Margin** | **IDR 705,000/kg** |
| a. | Labor income share | Not calculated |
| b. | Other input contribution | **78.48 %** |
| c. | Value-added share* | **21.52 %** |

**Note:** *Labor income was not recorded in the calculation because the entire production process was carried out by the business owner without a formal wage system.

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## AUTHOR CONTRIBUTIONS

**Resti Nurmala Dewi:** Writing – original draft, Methodology, Data curation, Conceptualization, Supervision. **Medal Lintas Perceka:** Writing – review & editing, Conceptualization, Supervision. **Kholifatul Imroatin:** Investigation, Formal analysis, Data curation.

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## DECLARATION OF INTERESTS

The authors declare that there are no known competing financial interests or personal ties that could have influenced the work described in this paper.

## DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## REFERENCES

Anggraini, F. J., N. Ula, A. N. Sari, & M. Sestiono (2024). Pemanfaatan Bahan Dasar Lokal Kerang Hijau dan Daun Kelor Menjadi Inovasi Produk Baru Pukelor (Puding Kerang Hijau dan Daun Kelor). In: *Seminar Hasil Pengabdian Kepada Masyarakat dan Kuliah Kerja Nyata*. Gresik: Universitas Muhammadiyah Gresik.

Arcales, J. A. A. & L. M. Nacional (2019). Quality Changes of Chilled Green Mussel (*Perna viridis*) Pre-Treated with Organic Acids and Sodium Tripolyphosphate. *Current Research in Nutrition and Food Science Journal 7*(3), 894–904. https://doi.org/10.12944/CRNFSJ.7.3.28

Badan Standardisasi Nasional (2011). *SNI 2346:2011 Tentang Petunjuk Pengujian Organoleptik dan/atau Sensori pada Produk Perikanan*. Jakarta: Badan Standardisasi Nasional.

— (2017). *SNI 7266:2017 Tentang Bakso Ikan*. Jakarta: Badan Standardisasi Nasional.

Basri & A. M. Rizki (2023). Penanganan Kerang Hijau (*Perna viridis*) Sebagai Olahan Produk Kamaboko. *SEMAH: Jurnal Pengelolaan Sumberdaya Perairan 7*(1), 30–37.

Biji, K. B., R. M. Shamseer, C. O. Mohan, C. N. Ravishankar, S. Mathew, & T. K. S. Gopal (2015). Effect of Thermal Processing on the Biochemical Constituents of Green Mussel (*Perna viridis*) in Tin-Free-Steel Cans. *Journal of Food Science and Technology 52*(10), 6804–6809. https://doi.org/10.1007/s13197-015-1757-8

Chakraborty, K. & D. Joseph (2015). Production and Characterization of Refined Oils Obtained from Indian Oil Sardine (*Sardinella longiceps*). *Journal of Agricultural and Food Chemistry 63*(3), 998–1009. https://doi.org/10.1021/jf505127e

Dewi, R. N., I. G. A. Budiadnyani, D. Febrianti, & D. F. Putrivenn (2024). Pengujian Organoleptik dan Deteksi Logam Berat pada Bahan Baku dan Produk Bakso Ikan Lemuru (*Sardinella lemuru*) dari Selat Bali. *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan 18*(2), 147. https://doi.org/10.15578/jpbkp.v18i2.973

Fadhallah, E. G., P. Navisa, S. Susilawati, & R. Sugiharto (2024). Sensory and Physicochemical Properties of Threadfin Bream (*Nemipterus nemurus*) Meatballs from Breadfruit and Tapioca Flour Formulations. *Jurnal Pengolahan Hasil Perikanan Indonesia 27*(11), 990–1005. https://doi.org/10.17844/jphpi.v27i11.56669

FAO & WHO (2012). *Code of Practice for Fish and Fishery Products*. 2nd ed. Rome: Food and Agriculture Organization of the United Nations.

Feng, X., C. Fu, & H. Yang (2017). Gelatin Addition Improves the Nutrient Retention, Texture and Mass Transfer of Fish Balls without

Altering Their Nanostructure during Boiling. *LWT 77*, 142–151. https://doi.org/10.1016/j.lwt.2016.11.024

Fitriah, E., Y. Maryuningsih, & E. Roviati (2018). Pemanfaatan Daging dan Cangkang Kerang Hijau (*Perna viridis*) Sebagai Bahan Olahan Pangan Tinggi Kalsium. In: *Proceeding of The 7th University Research Colloquium 2018: Bidang MIPA dan Kesehatan*. Surakarta: STIKES PKU Muhammadiyah Surakarta, pp. 412–423.

Gumilar, I., S. A. Widjaja, R. I. Pratama, & A. Nurhayati (2021). Analysis of Value Added of Catfish Meatballs in Bandung Regency, West Java, Indonesia. *Asian Journal of Fisheries and Aquatic Research 15*(3), 18–25. https://doi.org/10.9734/ajfar/2021/v15i330330

Hayami, Y., T. Kawagoe, Y. Morooka, & M. Siregar (1987). *Agricultural Marketing and Processing in Upland Java: A Perspective from a Sunda Village*. Bogor: CGPRT Centre.

Huang, X., Q. Liu, P. Wang, C. Song, H. Ma, P. Hong, & C. Zhou (2024). Tapioca Starch Improves the Quality of *Virgatus nemipterus* Surimi Gel by Enhancing Molecular Interaction in the Gel System. *Foods 13*(1), 169. https://doi.org/10.3390/foods13010169

Huss, H. H. (1995). *Quality and Quality Changes in Fresh Fish*. FAO Fisheries Technical Paper No. 348. Rome: Food and Agriculture Organization of the United Nations.

Khotimah, K., I. Kusumaningrum, & R. N. Afiah (2024). Profil Tekstur dan Uji Hedonik Bakso Ikan Lele dengan Penambahan Tepung Ubi Kelapa (*Dioscorea alata*). *Jurnal Pengolahan Hasil Perikanan Indonesia 27*(8), 693–705. https://doi.org/10.17844/jphpi.v27i8.50811

Kingwascharapong, P., J. Janthueng, P. Kongsorn, S. Sanprasert, N. Pansawat, N. Wannawisan, & K. Hunsakul (2024). Development of Seasoned Green Mussel (*Perna viridis*) with Sodium Reduction Using Stealth Reduction Approaches. *Future Foods 10*, 100441. https://doi.org/10.1016/j.fufo.2024.100441

Lee, R., A. Lovatelli, & L. Ababouch (2008). *Bivalve Depuration: Fundamental and Practical Aspects*. FAO Fisheries Technical Paper No. 511. Rome: Food and Agriculture Organization of the United Nations.

Lestari, N. I., N. Herawati, A. Putra, A. Z. Alami, K. F. Suebu, M. I. Indrawan, R. I. Darmawan, & R. Adiyatma (2022). Inovasi Pembuatan Kreasi Olahan Makanan Sambal Kerang Hijau di Kelurahan Kota Karang Raya. *Jurnal Pengabdian Kepada Masyarakat BUGUH 2*(2), 56–62.

Manurung, F. N., W. Widianingsih, I. Widowati, & R. Hartati (2026). Length–Weight Relationships and Growth Characteristics of Green Mussels (*Perna viridis*) in the Waters of Tambak Lorok, Semarang. *Jurnal Kelautan Tropis 29*(2), 186–196. https://doi.org/10.14710/jkt.v29i2.31616

Meng, X., D. Wu, Z. Zhang, H. Wang, P. Wu, Z. Xu, Z. Gao, B. K. Mintah, & M. Dabbour (2022). An Overview of Factors Affecting the Quality of Beef Meatballs: Processing and Preservation. *Food Science & Nutrition 10*(6), 1961–1974. https://doi.org/10.1002/fsn3.2812

Ngamel, A. K. (2015). Analisis Usaha dan Nilai Tambah Pengolahan Dodol Rumput Laut Skala Rumah Tangga di Desa Loon, Kecamatan Kei Kecil, Kabupaten Maluku Tenggara. *Jurnal Sains Terapan 5*(1), 40–49.

Nuñal, S. N., R. B. Parcon, S. B. Logronio, N. H. N. Cartago, & M. F. S. Muegue (2023). Nutritional Evaluation of Green Mussel *Perna viridis* (Linnaeus, 1758) and Brown Mussel *Modiolus modulaides* (Röding, 1798) From Panay Island, Philippines. *Asian Fisheries Science 36*(3). https://doi.org/10.33997/j.afs.2023.36.3.004

Qamarani, J. M. F. P., L. Santri, Mujiburrahmad, & Bagio (2026). Value-Added Analysis of Mackerel Tuna (*Euthynnus affinis*) Processing into Keumamah: A Household Enterprise Case Study in Lhokseumawe, Aceh. *Jurnal Bisnis Tani 12*(1), 92–102. https://doi.org/10.35308/jbt.v12i1.400

Rajasekaran, B., B. Subbiah, N. M. Stephen, M. Nagarajan, & S. Muniasamy (2021). Design, Fabrication, and Validation of Ohmic Heater to Process Green Mussel Meat. *Journal of Food Processing and Preservation 45*(6), e15511. https://doi.org/10.1111/jfpp.15511

Rohmat, S., Suratmi, Yuliyanti, Wininda, R. Fawziyah, Salsabila, & K. Khotimah (2024). Pertambahan Nilai Olahan Potensi Kerang Hijau untuk Meningkatkan Ekonomi dan Gizi Keluarga di Desa Sambeng. *Etos: Jurnal Pengabdian Masyarakat 6*(1), 63–76.

Saputro, A. G., S. Supardi, & S. W. Ani (2018). Analisis Usaha Agroindustri Penggilingan Padi Kecil di Kabupaten Sragen. *SEPA: Jurnal Sosial Ekonomi Pertanian dan Agribisnis 15*(1), 50. https://doi.org/10.20961/sepa.v15i1.25050

Sorio, J. C. & J. A. A. Arcales (2022). Development and Acceptability of Value-Added Products from Green Mussel (*Perna viridis*) in Samar, Philippines. *Food Research 6*(3), 215–219. https://doi.org/10.26656/fr.2017.6(3).320

Tee, E. T. & L. F. Siow (2017). Effect of Tapioca and Potato Starch on the Physical Properties of Frozen Spanish Mackerel (*Scomberomoru guttatus*) Fish Balls. *International Food Research Journal 24*(1), 182–190.

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