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DEVELOPMENT OF GRILLED PEMPEK (PEMPEK BAKU) USING POMFRET AND YELLOW SWEET POTATO AS A HEALTHY SNACK

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ABSTRACT

High consumption of low-nutrient, ready-to-eat foods among the Indonesian population has driven the need for more nutritious food product innovations. Grilled pempek made with freshwater pomfret and yellow sweet potato (Pempek BAKU) was developed as a healthy snack alternative with broad community acceptance potential. This study aimed to: (1) determine the optimal Pempek BAKU formula, (2) identify appropriate packaging, (3) assess community acceptance level, (4) analyze nutritional content, and (5) determine the selling price and Break Event Point (BEP). The study employed a Research and Development (R&D) approach with the 4D model (Define, Design, Develop, Disseminate), conducted from September 2025 to April 2026. Data were collected from 2 expert panelists, 30 semi-trained student panelists, and 80 general community panelists. Results showed: (1) the optimal formula comprised 10% yellow sweet potato substitution and 100% freshwater pomfret; (2) packaging consisted of OPP plastic as primary packaging and an oil-resistant mica box as secondary packaging with a product label; (3) the hedonic test yielded an overall mean acceptance score of 4.31, with flavor (4.23), aroma (4.25), texture (4.05), color (4.25), and packaging (4.18) scores, indicating positive community acceptance; (4) each 35-gram serving contained 57 kcal total energy, 3 g protein (5% RDA), 11 g carbohydrates (3% RDA), less than 1 g total fat, and less than 1 g dietary fiber; and (5) the selling price was set at IDR 30,000 per box of 10 pieces with a 40% mark-up, with BEP reached at 6 pieces.

Keywords:
grilled pempek; pomfret; yellow sweet potato

Tingginya konsumsi makanan cepat saji dan rendah nutrisi di kalangan masyarakat Indonesia mendorong perlunya inovasi produk pangan yang lebih bergizi. Pempek panggang dengan substitusi ubi jalar kuning dan ikan bawal air tawar (Pempek BAKU) hadir sebagai alternatif camilan sehat yang berpotensi diterima luas oleh masyarakat. Penelitian ini bertujuan untuk: (1) menentukan formula terbaik Pempek BAKU, (2) menentukan kemasan yang tepat, (3) mengetahui tingkat kesukaan masyarakat, (4) menganalisis kandungan gizi, serta (5) menentukan harga jual dan Break Even Point (BEP). Penelitian menggunakan metode R&D dengan model 4D (Define, Design, Develop, Disseminate), dilaksanakan pada September 2025–April 2026. Hasil menunjukkan: (1) formula terbaik menggunakan substitusi 10% ubi jalar kuning dan 100% ikan bawal; (2) kemasan menggunakan plastik OPP sebagai kemasan primer dan kotak mika berlapis anti-minyak sebagai kemasan sekunder; (3) uji kesukaan memperoleh rata-rata penerimaan keseluruhan 4,31; (4) setiap sajian 35 gram mengandung energi 57 kkal, protein 3 gram (5% AKG), karbohidrat 11 gram (3% AKG); dan (5) harga jual Rp30.000/box dengan BEP 6 buah pempek.

1. Introduction

The growing trend of high consumption of fast food and low-nutrient products among Indonesian society represents a significant public health concern. According to the 2023 Indonesian Health Survey (Survei Kesehatan Indonesia/SKI), the proportion of the population consuming unhealthy food patterns including fried foods, instant noodles, processed foods with preservatives, and high-sugar items remains considerably high. These foods are generally rich in simple carbohydrates and saturated fats while being deficient in balanced nutrients, yet are favored due to their palatability, accessibility, and affordability [1]. This dietary pattern is associated with elevated risks of vitamin deficiencies, obesity, and degenerative diseases [2]. Addressing this issue calls for innovative food product development that incorporates locally available, nutrient-dense ingredients as functional substitutes.

Yellow sweet potato (*Ipomoea batatas L.*) is a nutritionally rich tuberous crop ranked as the sixth most important food plant globally, with China leading world production in a market valued at USD 45 trillion. In Indonesia, sweet potato production reached 1,424,147 tons in 2021, down from 1,604,181 tons the previous year, primarily due to shrinking harvest areas estimated at approximately 67,738 hectares in 2021 [3]. Yellow sweet potato contains 119 kcal energy, 0.5 g protein, 0.4 g fat, 25.1 g carbohydrate, and 4.2 g dietary fiber per 100 g [4]. Despite being widely available, its utilization remains limited to simple preparations such as boiling, frying, or traditional desserts (kolak), with relatively few applications in innovative food products [5]. To complement its fiber and carbohydrate profile, pairing yellow sweet potato with a high-protein local ingredient is considered a promising strategy for developing a more nutritionally balanced food product.

Freshwater pomfret (*Colossoma macropomum*) is an aquaculture species originating from South American waters, known for rapid growth reaching up to 30 kg body weight and 90 cm length in natural habitats [6]. Indonesian production of freshwater pomfret in 2024 was recorded at 480,723 tons, considerably lower than marine fish production at 7,330,891 tons, partly attributable to the reduced availability of inland water bodies [7]. From a nutritional standpoint, freshwater pomfret provides 91 kcal energy, 19 g protein, and 1.7 g fat per 100 g fresh flesh, making it an ideal protein source. Additionally, it is rich in calcium, vitamins A, D, and B12, which are important for neural function and overall health [8]. Given its strong nutritional profile and underutilization as a processed food ingredient, freshwater pomfret presents considerable potential as the primary protein base in a reformulated traditional snack product.

Pempek is a traditional fishcake from South Sumatra, widely consumed across Indonesia [9]. It is commonly served with a dark sweet-sour sauce (cuko) made from tamarind and various spices. Pempek panggang (grilled pempek) is a popular variant characterized by its dry, crispy texture with a filling of dried shrimp (ebi), sweet soy sauce, and bird's-eye chili. Despite its popularity, conventional pempek is limited nutritionally, relying primarily on fish protein and sago starch without significant dietary fiber or micronutrient contributions [10]. This nutritional shortcoming, combined with the broad consumer familiarity of pempek as a platform product, creates an opportunity to develop an enriched formulation using underutilized local ingredients.

Previous studies have individually explored the utilization of yellow sweet potato in biscuits [11] and ice cream [12], and the incorporation of pomfret in composite-flour puff pastry [8]. However, no prior study has simultaneously combined yellow sweet potato and freshwater pomfret in a single pempek-based product. This research gap represents the novelty of the present study: developing Pempek BAKU (BAwal and ubi jalar KUning) as a nutritionally enhanced grilled pempek variant that

leverages local food ingredients while meeting contemporary consumer health demands. Building on this identified gap, the present study was structured around five specific research objectives.

The objectives of this study were to (1) determine the optimal Pempek BAKU formula, (2) identify appropriate primary and secondary packaging, (3) assess community acceptance through hedonic testing, (4) analyze nutritional content via proximate analysis, and (5) determine the selling price and Break Even Point (BEP) as indicators of commercial viability. To achieve these objectives, a Research and Development (R&D) approach employing the four-stage 4D model Define, Design, Develop, and Disseminate was adopted, combining systematic product formulation, expert and consumer sensory evaluation, laboratory proximate analysis, and economic feasibility assessment.

2. Method

2.1 Research Design

This study employed a Research and Development (R&D) approach following the 4D development model consisting of four sequential stages: Define, Design, Develop, and Disseminate [13]. The research was conducted from September 2025 to April 2026 across three locations: (1)Culinary Arts Laboratory, Faculty of Vocational Studies, Universitas Negeri Yogyakarta (Wates Campus) for product development and sensory testing; (2) Auditorium Courtyard of the same faculty for large-scale consumer hedonic testing; and (3) Chem-Mix Pratama Laboratory, Bantul, for proximate analysis.

2.2 Materials

The primary materials used in the developed product (F1 formula) comprised: freshwater pomfret (250 g), sago flour (135 g), yellow sweet potato purée (15 g), dried shrimp/ebi (50 g), green bird's-eye chili (5 pcs), sweet soy sauce (30 g), garlic (2 cloves), salt (7 g), and water (150 ml). The reference recipe used Spanish mackerel as the protein source with no sweet potato substitution. Yellow sweet potato was steamed at 100°C for 20–30 minutes then mashed into a smooth purée prior to incorporation into the dough [12].

2.3 Product Development (4D Stages)

Define stage: Three reference recipes were tested using Spanish mackerel as the base protein to identify the optimal benchmark recipe. Sensory evaluation was conducted by 2 expert panelists and 3 semi-trained panelists, resulting in Reference Recipe 3 (R3) being selected as the benchmark based on highest mean sensory scores across all attributes.

Design stage: Three formulations were developed by substituting yellow sweet potato purée at 10% (F1), 20% (F2), and 30% (F3) of the sago flour weight, while replacing 100% of Spanish mackerel with freshwater pomfret. The formulations were evaluated by 5 panelists (2 experts + 3 semi-trained).

Develop stage: The selected formulation (F1) underwent expert validation (n=2) followed by a limited consumer preference test (n=30 semi-trained panelists/culinary arts students). Packaging design was developed and evaluated at this stage.

Disseminate stage: Large-scale consumer acceptance testing was conducted with 80 untrained general-public panelists at the Wonderroots 2025 food festival. Both the reference recipe and Pempek BAKU were evaluated simultaneously.

2.4 Sensory Evaluation

Hedonic (preference) testing employed a five-point Likert scale (1 = strongly dislike, 2 = dislike, 3 = neutral, 4 = like, 5 = strongly like) adapted from standard food sensory evaluation protocols [14]. Evaluated attributes included color, aroma, flavor, texture, packaging appearance, and overall acceptance. Statistical analysis was performed using the paired-sample t-test ($p < 0.05$/ $p > 0.05$) to determine significant differences between the reference product and Pempek BAKU.

2.5 Proximate Analysis

Nutritional analysis of both the reference product and Pempek BAKU (F1) was conducted in duplicate at the Chem-Mix Pratama Laboratory, Bantul, Yogyakarta (February 2026). Parameters analyzed included moisture content, ash, protein, fat, carbohydrate (by difference), and crude fiber. Results were analyzed using the paired-sample t-test. Nutritional information per serving (35 g) was calculated based on Indonesian BPOM Regulation No. 9/2019 and Ministry of Health RDA values [4].

2.6 Price and Break Even Point Analysis

Selling price was determined using the Cost-Plus Pricing method with a 40% mark-up applied to total production cost. Break Even Point (BEP) was calculated using standard fixed-cost and variable-cost formulas to determine minimum units required to avoid financial loss [15].

3. Results and Discussion

3.1 Define Stage: Reference Recipe Selection

Three reference recipes sourced from published recipes and previous research [9, 10] were prepared using Spanish mackerel as the protein source. The recipes were evaluated for sensory attributes by expert and semi-trained panelists. As presented in Table 1, all three recipes produced products of similar roundish-flattened shape (6 cm diameter), a slightly yellowish-white color, and a savory-sweet-spicy flavor profile.

Tabel 1. Reference Recipe Grilled Pempek

No	Ingridients	Recipe 1	Recipe 2	Recipe 3
1.	Spanish mackerel	500 gr	500 gr	250 gr
2.	Sago flour	300 gr	400 gr	150 gr
3.	Dried shrimp (ebi)	200 gr	200 gr	50 gr
4.	Green chili	100 gr	100 gr	5 pcs
5.	Sweet soy sauce	100 gr	100 gr	30 gr
6.	Garlic	3 cloves	-	2 cloves
7.	Salt	10 gr	7 gr	7 gr
8.	Water	300 ml	200 ml	150 ml

Source :
Resep 1 : Cookpad (https://cookpad.com/id/resep/17239529-329-pempek-tunu-ikantenggiri
Resep 2 : (Febryan, 2021)
Resep 3 : https://resepkoki.id/resep/resep-pempek-panggang/

However, Recipe 1 & 2 produced a chewier texture due to higher sago content and exhibited a more prominent fish aroma due to the absence of garlic. Recipe 3 (R3) achieved the highest overall mean sensory score of 4.0 and was selected as the benchmark for product development. As can be seen in the following data :

Tabel 2. Mean sensory test define stage

Sensory Attribute	Mean		
	R1	R2	R3
Shape	3.6	3.2	4
Size	3.6	3.6	4
Color	3.6	3.6	4
Aroma	3.8	3.6	4.4
Taste	4	3.6	4.2
Texture	3.4	3	4
Overall	3.8	3.4	4

3.2 Design Stage: Formulation Development

Based on R3, three development formulations were produced by substituting yellow sweet potato purée at 10% (F1), 20% (F2), and 30% (F3) of the sago flour weight, while fully replacing Spanish mackerel with freshwater pomfret.

Table 3. Pempek BAKU Formulation

No.	Ingredients	Reference Recipe (R)	F1 (10%)	F2 (20%)	F3 (30%)
1	Freshwater pomfret	–	250 g	250 g	250 g
2	Spanish mackerel (reference)	250 g	–	–	–
3	Sago flour	150 g	135 g	120 g	105 g
4	Yellow sweet potato purée	–	15 g	30 g	45 g
5	Dried shrimp (ebi)	50 g	50 g	50 g	50 g
6	Green bird's-eye chili	5 pcs	5 pcs	5 pcs	5 pcs
7	Sweet soy sauce	30 g	30 g	30 g	30 g
8	Garlic	2 cloves	2 cloves	2 cloves	2 cloves
9	Salt	7 g	7 g	7 g	7 g
10	Water	150 ml	150 ml	150 ml	150 ml

Table 4 presents the mean sensory scores from the design-stage evaluation. F1 consistently outperformed F2 and F3 across all sensory attributes. Increasing the proportion of sweet potato purée progressively darkened the product color from slightly orange-white (F1) to dark orange-brown (F3), and rendered the texture increasingly moist and soft, deviating from the characteristic chewiness expected in grilled pempek. F1, with the smallest deviation from reference sensory standards, was selected for further development.

Table 4. Mean Sensory Scores

Sensory Attribute	Reference Recipe	F1 (10%)	F2 (20%)	F3 (30%)
Shape	4.4	4.2	4.0	3.8
Size	4.4	4.2	4.2	4.0
Color	4.4	4.0	3.8	3.6
Aroma	4.6	4.0	3.6	4.0
Flavor	4.4	3.6	3.0	3.2
Texture	4.8	4.2	3.8	3.8
Overall	4.6	4.2	3.9	3.4

3.3 Develop Stage: Validation and Packaging

Expert validation of F1 versus the reference recipe (R3) was conducted by two culinary experts. As shown in Table 5, the developed product (F1) received higher expert evaluation scores (mean 4.5) compared to the reference recipe (mean 4.0) across all attributes, including color, aroma, flavor, texture, and overall quality. Both experts agreed that the product demonstrated satisfactory sensory quality while exhibiting improvements in color and aromatic profile due to the yellow sweet potato incorporation. Minor feedback was noted regarding the consistency of the cuko filling spiciness level, which was addressed before the limited consumer test.

Table 5. Expert Validation Scores

Sensory Attribute	Reference Product (Mean)	Developed Product (Mean)
Color	4.0	4.5
Aroma	4.0	4.5
Flavor	4.0	4.5
Texture	4.0	4.5
Overall	4.0	4.5

Fig 1. Packaging Pempek BAKU
Source : (M. Ghozy, 2026)

The packaging system designed for Pempek BAKU consists of two layers: an OPP (oriented polypropylene) plastic bag (8×12 cm) as the primary packaging containing one individually wrapped piece (30–35 g), and a white mica box with a transparent lid (7×14 cm) as secondary packaging containing 10 pieces, sealed with an informational product sticker. The primary packaging was selected for its moisture resistance and transparency, while the secondary packaging was chosen for its visual appeal and ability to display the product.

Limited consumer acceptance testing with 30 semi-trained panelists (culinary arts students) using paired t-test analysis revealed no statistically significant differences ($p > 0.05$) between reference and developed products for aroma ($p = 0.67$), flavor ($p = 0.08$), texture ($p = 0.40$), and overall acceptance ($p = 0.55$). Only color showed a marginally significant difference ($p = 0.05$), attributed to the slight orange hue introduced by yellow sweet potato beta-carotene pigments.

Table 6. Semi-trained Acceptance Scores: Develop Stage (n = 30 panelists)

Sensory Attribute	Reference (Mean ± SD)	Pempek BAKU (Mean ± SD)	p-value	Significance
Flavor	4.43 ± 0.73	4.37 ± 0.76	0.08	ns
Aroma	4.40 ± 0.67	4.30 ± 0.70	0.67	ns
Texture	4.47 ± 0.68	4.33 ± 0.66	0.40	ns
Color	4.23 ± 0.73	4.33 ± 0.84	0.05	s
Overall	4.57 ± 0.63	4.53 ± 0.63	0.55	ns

Note: ns = not significant ($p > 0.05$), s = significant ($p < 0.05$)

3.4 Disseminate Stage: Community Acceptance

The large-scale hedonic test conducted with 80 untrained general-public panelists at the Wonderroots 2025 food festival yielded positive acceptance results for Pempek BAKU across all evaluated attributes. Table 7 presents comparative mean scores between the reference product and Pempek BAKU. Pempek BAKU consistently outperformed the reference product across all attributes, recording mean scores of 4.23 for flavor, 4.25 for aroma, 4.05 for texture, 4.18 for packaging, 4.25 for color, and 4.31 for overall acceptance. Paired t-test analysis confirmed no statistically significant differences between the two products across all attributes ($p > 0.05$), indicating that the substitution did not negatively affect consumer acceptance.

Table 7. Consumer Acceptance Scores: Disseminate Stage (n = 80 panelists)

Sensory Attribute	Reference (Mean ± SD)	Pempek BAKU (Mean ± SD)	p-value	Significance
Flavor	3.95 ± 0.82	4.23 ± 0.74	0.678	ns
Aroma	4.05 ± 0.76	4.25 ± 0.70	0.681	ns
Texture	3.74 ± 1.05	4.05 ± 0.84	0.878	ns
Packaging	3.95 ± 0.72	4.18 ± 0.65	0.706	ns
Color	3.98 ± 0.74	4.25 ± 0.80	0.369	ns
Overall	4.06 ± 0.76	4.31 ± 0.68	0.702	ns

Note: ns = not significant (p > 0.05)

The overall acceptance score of 4.31 indicates that Pempek BAKU was well-received by the community, with the product falling between the "like" and "strongly like" categories on the hedonic scale. This result supports the viability of freshwater pomfret and yellow sweet potato as effective ingredient substitutions in grilled pempek without compromising consumer acceptability.

3.5 Nutritional Composition

Proximate analysis results comparing the reference product and Pempek BAKU are presented in Table 8. Significant differences ($p < 0.05$) were found in moisture content, protein, and carbohydrate levels between the two products. Pempek BAKU showed a higher moisture content (55.76% vs. 53.83%), higher protein content (8.94% vs. 8.24%), and lower carbohydrate content (30.48% vs. 33.16%). The increase in moisture and protein can be attributed to the higher water-holding capacity and protein profile of freshwater pomfret relative to Spanish mackerel. The reduction in carbohydrate content aligns with the partial substitution of sago flour with yellow sweet potato purée.

Table 8. Proximate Analysis: Reference Product vs. Pempek BAKU

Nutritional Component	Reference Recipe (%)	Pempek BAKU (%)	p-value	Significance
Moisture	53.83 ± 0.03	55.76 ± 0.08	0.001	Significant
Ash	1.86 ± 0.01	2.05 ± 0.07	0.063	Not significant
Protein	8.24 ± 0.08	8.94 ± 0.03	0.008	Significant
Fat	0.42 ± 0.07	0.56 ± 0.14	0.339	Not significant
Carbohydrate	33.16 ± 0.20	30.48 ± 0.14	0.004	Significant
Crude fiber	2.49 ± 0.01	2.21 ± 0.12	0.080	Not significant

Although the difference in crude fiber content between the two products was not statistically significant ($p = 0.080$), this is attributed to the limited proportion of sweet potato substitution (10% of sago flour weight), which corresponds to only 15 g of purée per batch. To achieve a more meaningful increase in dietary fiber, a higher substitution level would be required;

however, sensory evaluation findings indicate that formulations beyond 10% negatively impact texture quality and consumer acceptance. These findings suggest a practical upper boundary for sweet potato incorporation in this product type.

Table 9. Nutritional Information per Serving of Pempek BAKU

Nutrient	Amount per 35 g serving	% Daily Value (RDA)
Total energy	57 kcal	–
Energy from fat	2 kcal	–
Total fat	<1 g	0%
Protein	3 g	5%
Carbohydrate	11 g	3%
Dietary fiber	<1 g	2%

**% Daily Value based on 2,150 kcal/day reference energy intake per Indonesian Ministry of Health AKG 2019. Individual needs may vary.*

Table 9 presents the complete nutritional information per 35-gram serving of Pempek BAKU. Each serving contains 57 kcal total energy, with 3 g protein (5% RDA), 11 g carbohydrates (3% RDA), less than 1 g total fat (0% RDA), and less than 1 g dietary fiber (2% RDA). As a snack product, Pempek BAKU provides a reasonable protein contribution at 5% of the daily recommended protein intake per serving. The relatively low fat content (<1 g) is consistent with the grilled (non-fried) preparation method, making it a preferable option compared to deep-fried snack alternatives. The low carbohydrate and caloric density position Pempek BAKU as a suitable light snack for health-conscious consumers.

3.6 Selling Price and Break Even Point

Production cost analysis yielded a total cost of IDR 34,860 per batch of 18 pieces, comprising raw material costs (IDR 29,050), equipment depreciation (10% = IDR 2,905), and labor costs (10% = IDR 2,905). Applying a 40% mark-up, the calculated selling price is IDR 3,000 per piece, or IDR 30,000 per box of 10 pieces. The BEP was calculated at 6 pieces per batch (IDR 16,600 in revenue), indicating that profitability begins after the sale of only 6 out of 10 pieces per box a commercially viable threshold for small-scale production. Table 10 compares Pempek BAKU pricing with competing products in the market.

Table 10. Price Comparison: Pempek BAKU vs. Competing Market Products

Product Name	Weight/piece	Price (IDR)	Source/Brand
Pempek BAKU	35 g	IDR 3,000	M. Ghozy Al Qushoyyi (this study)
Pempek Mix	40 g	IDR 5,500	Pempek Candy
Pempek Panggang	30 g	IDR 6,000	Pempek Vico
Pempek Bakar	30 g	IDR 7,000	Pempek 123

As shown in Table 10, Pempek BAKU is priced competitively at IDR 3,000/piece (35 g), which is 45–57% lower than comparable grilled pempek products from established brands (IDR 5,500–7,000/piece). Despite the lower price point, Pempek BAKU offers a nutritional advantage through

its yellow sweet potato and freshwater pomfret incorporation, targeting health-conscious consumers in a growing functional snack market. The favorable pricing reflects the use of locally available freshwater pomfret as a more cost-effective alternative to marine fish species such as Spanish mackerel.

4. Conclusions

This study successfully developed Pempek BAKU, a nutritionally enhanced grilled pempek formulated with 100% freshwater pomfret and 10% yellow sweet potato purée substituted from sago flour. The optimal formula (F1) demonstrated satisfactory sensory quality comparable to the reference product across all evaluated attributes, with no statistically significant differences in community acceptance scores ($p > 0.05$). The product received an overall acceptance score of 4.31 out of 5 from 80 general-public panelists. Proximate analysis confirmed significant increases in protein content (8.94% vs. 8.24%) and moisture content in Pempek BAKU compared to the reference, while maintaining a low fat content (<1 g per serving) consistent with its grilled preparation. Each 35-gram serving delivers 57 kcal and 3 g protein (5% RDA). The selected two-layer packaging system and competitive pricing at IDR 30,000 per box of 10 pieces with a 40% mark-up support commercial viability, with BEP achieved at 6 pieces per box. Pempek BAKU demonstrates the potential for traditional Indonesian snack innovation using underutilized local ingredients. Future research is recommended to investigate higher substitution levels of yellow sweet potato in combination with modified processing techniques to enhance fiber content without compromising textural quality, as well as shelf-life studies and larger-scale market validation.

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