

## Principal Component of Protein-Dense Catfish-Tempeh Nuggets as a Local Stunting Intervention

### Komponen Utama Nugget Tempe Lele Padat Protein sebagai Intervensi Stunting Lokal

Yusransyah Yusransyah\*<sup>1</sup>, Sofi Nurmay Stiani<sup>2</sup>, Indah Ayu Nur Hasanah<sup>3</sup>, Andrian Maulana Fauzi<sup>4</sup>, Olin Najilah Ofsah<sup>5</sup>, Baha Udin<sup>6</sup>

<sup>1,2,4,6</sup>Pharmacy Study Program, Sekolah Tinggi Ilmu Kesehatan Salsabila Serang

<sup>3</sup>Midwifery Professional Education Study Program, Sekolah Tinggi Ilmu Kesehatan Salsabila Serang

<sup>5</sup>Midwifery Study Program, Sekolah Tinggi Ilmu Kesehatan Salsabila Serang

\*E-mail: yusransyah@iai.id<sup>1</sup>, sofia240586@gmail.com<sup>2</sup>, nurhasanaindahayu@gmail.com<sup>3</sup>, maulanaadrian9181@gmail.com<sup>4</sup>, olinnajilaho@gmail.com<sup>5</sup>, bahasfarma@gmail.com<sup>6</sup>

#### Abstract

*Stunting remains a persistent nutritional challenge in Indonesia, requiring evidence-based, locally developed food interventions that are both nutritious and appealing to children. This study aimed to develop and assess "Nulte," a catfish-tempeh nugget formulation, as a sustainable, protein-dense local food innovation to support stunting prevention. Three formulations with varying catfish-to-tempeh ratios (1:1, 2:1, and 1:2) were prepared using standardized community-based procedures. Each product underwent proximate composition testing following AOAC methods, and sensory evaluation using a 5-point hedonic scale by 30 untrained panelists (local mothers and children). Data were analyzed statistically using ANOVA, MANOVA, and Principal Component Analysis (PCA) to identify the optimal formulation. Formula 2 (2:1) achieved the highest protein content (15.33 g/100 g), the best sensory acceptance (overall 4.2 ± 0.4), and provided up to 76.65 % of daily protein needs for children aged 1–3 years, significantly outperforming other formulas in energy and taste (p < 0.05). PCA results indicated that Formula 2 showed the strongest clustering between nutritional quality and sensory preference dimensions. These findings demonstrate that Nulte nuggets effectively combine animal and plant proteins into a child-friendly, nutrient-dense product. Their simple preparation and use of locally available ingredients make them a promising scalable intervention for community-level stunting prevention in Indonesia.*

**Keywords:** Nugget Nulte, Catfish, Tempeh, Stunting, Prevention, Nutrition

#### Abstrak

*Stunting masih menjadi tantangan gizi yang persisten di Indonesia dan memerlukan intervensi pangan lokal berbasis bukti yang bergizi sekaligus menarik bagi anak-anak. Kegiatan ini bertujuan untuk mengembangkan dan mengevaluasi "Nulte", nugget lele-tempe sebagai inovasi pangan lokal padat protein yang berpotensi mendukung pencegahan stunting di tingkat komunitas. Tiga formulasi dengan rasio lele dan tempe yang berbeda (1:1, 2:1, dan 1:2) dikembangkan menggunakan prosedur standar berbasis masyarakat. Setiap produk diuji komposisi proksimatnya mengikuti metode AOAC, serta dilakukan uji sensori dengan skala hedonik 5 poin oleh 30 panelis tidak terlatih (ibu dan anak setempat). Data dianalisis menggunakan ANOVA, MANOVA, dan Analisis Komponen Utama (PCA) untuk menentukan formulasi paling optimal. Formulasi 2 (rasio 2:1) menunjukkan kandungan protein tertinggi (15,33 g/100 g), tingkat penerimaan keseluruhan terbaik (4,2 ± 0,4), serta mampu memenuhi hingga 76,65% kebutuhan protein harian anak usia 1–3 tahun, dengan perbedaan bermakna pada energi dan rasa (p < 0,05). Hasil PCA mengonfirmasi bahwa Formulasi 2 memiliki keseimbangan terbaik antara mutu gizi dan kesukaan sensori. Temuan ini menunjukkan bahwa nugget Nulte berhasil mengombinasikan sumber protein hewani dan nabati dalam bentuk pangan yang padat gizi, mudah diterima, dan berbasis bahan lokal. Produk ini berpotensi dikembangkan secara luas sebagai intervensi gizi komunitas untuk membantu menurunkan angka stunting di Indonesia.*

**Kata kunci:** Nugget Nulte, Lele, Tempe, Stunting, Pencegahan, Nutrisi

## 1. INTRODUCTION

Stunting remains one of Indonesia's most urgent public health challenges, affecting a significant proportion of children under five (Astuti et al., 2025). According to the 2018 Basic

Health Research (Riskesmas), the national stunting prevalence stood at 30.8%. Although it declined to 21.6% by 2022, the rate still exceeds the global target of under 14% by 2024 (Prameswari et al., 2023). Recent data from the Indonesian Ministry of Health (2024) indicate that despite various interventions, nearly 4.5 million Indonesian children under five remain stunted, reflecting persistent inequalities in nutrition access across provinces. Globally, the World Health Organization (Yanti et al., 2024) estimates that 148 million children under five suffer from stunting, most of whom live in low- and middle-income countries (LMICs), including Indonesia. Stunting not only restricts physical growth but also reduces cognitive potential, academic achievement, and economic productivity in adulthood (UNICEF et al., 2023).

The Sustainable Development Goals (SDG 2.2) emphasize ending all forms of malnutrition by 2030, with stunting reduction as a key indicator of progress. However, achieving this target requires not only policy alignment but also community-driven, culturally acceptable food interventions (FAO & WHO, 2024). In Indonesia, dietary diversity remains a major issue—many households depend heavily on carbohydrate-based staples, while animal protein and micronutrient-rich foods are limited in daily consumption (Hariawan et al., 2024; Kementerian Kesehatan RI, 2024). Consequently, children are vulnerable to chronic undernutrition, especially in rural and low-income communities where food insecurity persists (Dewi et al., 2024). Therefore, developing practical, affordable, and locally sourced nutrition innovations is essential to accelerate stunting reduction.

One promising strategy is to leverage locally available, nutrient-rich foods to help meet children's daily needs for protein, fat, carbohydrates, and essential micronutrients. Recent literature supports the use of *local functional foods*—foods made from indigenous ingredients that are rich in bioavailable nutrients and easily accepted by local communities—as a sustainable nutrition strategy (Hati et al., 2025; Syitra et al., 2025). Indonesia has abundant protein sources, including freshwater fish and soy-based products, which are often underutilized in child nutrition programs (Werdiningsih et al., 2023). Catfish (*Clarias gariepinus*) is a high-quality animal protein containing all essential amino acids, omega-3 fatty acids, and micronutrients such as iron, zinc, and phosphorus (Abdel-Mobdy et al., 2021). Meanwhile, tempeh, Indonesia's staple plant-based protein, provides rich sources of fiber, B vitamins, and bioavailable iron, as well as probiotic benefits due to its fermentation process (Teoh et al., 2024). Several studies have reported the macronutrient composition of both catfish and tempeh, highlighting their combined potential for combating childhood malnutrition (Idam & Degais, 2025; Rizzo, 2024; Shadyeva et al., 2019). Furthermore, interventions using either catfish or tempeh have shown positive outcomes in improving growth metrics among children at risk of stunting (Indriyani et al., 2023; Patmawati et al., 2022; Sihombing et al., 2024; Werdiningsih et al., 2023). However, delivering these foods in raw or traditional forms often faces resistance due to unappealing taste, inconsistent textures, and difficulties in preserving them for storage (Bland et al., 2018; Kustyawati et al., 2020; Tucker & Schrader, 2020). This underscores the need to develop a more appealing, stable, and child-friendly format, such as nuggets.

Previous studies have demonstrated that both catfish-based and tempeh-based interventions can improve growth metrics and reduce malnutrition among children (Indriyani et al., 2023; Patmawati et al., 2022). However, traditional forms of these foods often face challenges in acceptance among young children due to undesirable odor, texture, or taste (Bland et al., 2018; Kustyawati et al., 2020). Moreover, their short shelf life and limited processing versatility hinder wide-scale implementation (Tucker & Schrader, 2020). This highlights the need for reformulating these nutrient-rich ingredients into *child-friendly, stable, and appealing formats*, such as ready-to-eat nuggets.

Nuggets are widely accepted by children for their shape, taste, and ease of consumption, making them a strategic vehicle for delivering essential nutrients (Utami & Iwan, 2025; Veronica & Siregar, 2022). Studies indicate that food texture and flavor play a crucial role in child acceptance of new foods (Liu et al., 2024; Oliveira et al., 2023). Therefore, adapting local protein sources into nugget products can increase children's willingness to consume nutrient-dense

meals. Beyond acceptability, integrating catfish and tempeh into a single product also reflects the concept of *local food sovereignty*—utilizing community resources to meet nutritional needs sustainably (Wittman, 2023). Unlike typical commercial nuggets, which often lack balanced nutrition, our approach combines the best of local protein sources to enhance both health benefits and sensory acceptability.

Despite the increasing attention toward local protein-based food interventions, few studies have analyzed such innovations through a quantitative, multivariate approach to optimize nutrient and sensory properties. Most prior interventions focused solely on proximate composition or acceptance testing, without examining the multivariate relationships among sensory variables and nutritional outcomes. Thus, the present study introduces a novel analytical dimension by applying Principal Component Analysis (PCA) to identify the optimal balance between nutrition density and sensory appeal. PCA allows researchers to reduce complex data into key components, offering an objective means to determine which formulation best satisfies multiple desirable criteria (Ghosh & Chattopadhyay, 2012).

Therefore, this community service aims to develop and evaluate Nulte (catfish-tempeh) nuggets as a locally based, protein-dense, and child-friendly intervention for stunting prevention. Specifically, this study aims to: (1) formulate nuggets with varying ratios of catfish and tempeh, (2) evaluate their nutritional composition and sensory acceptability, and (3) identify optimal formulations using PCA. These findings are expected to contribute to community-based nutrition improvement efforts and provide an evidence-based model for scaling up local food innovations to address stunting in Indonesia.

## 2. METHOD

### Study Design and Setting

This study was conducted using an experimental design as part of a community-based participatory research and development (R&D) initiative. The primary objective was to formulate, evaluate, and optimize a functional food product, Nulte nuggets (catfish-tempeh), as a locally acceptable dietary intervention to prevent stunting. The community service activities were implemented on July 9, 2025, in Kemanisan Village, Jakarta, while the laboratory analyses were carried out at the DKI Jakarta Nutritional Health Laboratory (LABSKEDA), an accredited facility for food composition testing.

### Raw Material Preparation

The main ingredients included fresh catfish (*Clarias gariepinus*) and fermented soybean cake (tempeh). Both ingredients were sourced locally within 24 hours before processing to ensure optimal freshness and nutritional integrity. Supporting ingredients included wheat flour, tapioca starch, chicken eggs, garlic, shallots, iodized salt, pepper, sugar, and bread crumbs. These were supplemented with vegetable oil for frying.

For the catfish, the fish were gutted, descaled, cleaned, and steamed until fully cooked. The flesh was manually separated from bones and skin, minced finely, and cooled to room temperature. Tempeh was steamed briefly (5–10 minutes) to reduce microbial load and then mashed into a fine, uniform paste.

### Product Formulation

Three different formulations of Nulte nuggets were developed by varying the weight ratio of catfish to tempeh (see Table 1).

Table 1. Nugget formulations from minced catfish and mashed tempeh in different ratios.

Ingredients	Formula 1 (1:1)	Formula 2 (2:1)	Formula 3 (1:2)
Minced Catfish (g)	125	125	62.5
Mashed Tempeh (g)	125	62.5	125
Wheat Flour (g)	20	20	20
Tapioca Starch (g)	15	15	15
Egg (g)	50	50	50
Garlic (g)	5	5	5
Shallots (g)	5	5	5
Salt (g)	2	2	2
Pepper (g)	1	1	1
Sugar (g)	2	2	2
Bread Crumbs (g)	50	50	50

To each formula, 20g of wheat flour, 15g of tapioca starch, 50g of beaten egg, and a blend of 5g garlic, 5g shallots, 2g salt, 1g pepper, and 2g sugar were added. All ingredients were homogenized using a mixing bowl and a spatula until a consistent paste formed. The final mixture was molded manually into rectangular nugget shapes of uniform thickness. **Figure 1** shows the process of nugget fabrication.



Figure 1. Process of Nulte nugget preparation. Note: (A) fish cutting and cleaning, (B) weighing, (C) steaming, (D) flavor mixing, (E) adding and mixing other ingredients (including mashed tempeh and starch), and (F) adding breadcrumbs for crunchiness.

The nuggets were coated by dipping them in beaten egg and rolling them in breadcrumbs until fully covered. To improve structure and preserve integrity during storage, the nuggets were pre-steamed for 10–15 minutes and then cooled before being stored or fried.

### Sensory Evaluation

Sensory testing was conducted using a 5-point hedonic scale (1 = strongly dislike, 5 = strongly like). A total of 30 untrained panelists, comprising local mothers and school-aged children, participated in the evaluation. Participants were briefed on the procedure and provided informed consent before participation. Nugget samples were pan-fried until golden brown and served warm under uniform conditions. Each participant rated the color, aroma, taste, texture, and overall acceptability of all three formulations.

Responses were recorded using structured questionnaires administered via Google Forms. Data were compiled and analyzed descriptively by calculating mean scores and standard deviations for each attribute using the relevant formulas.

### **Nutritional Analysis**

A proximate analysis was performed on all three formulations using triplicate samples to determine the macronutrient composition of each Nulte nugget formula. All analyses were conducted at the Laboratory of Nutritional Health (LABSKEDA), DKI Jakarta, and adhered to standardized AOAC (Association of Official Analytical Chemists) protocols. The total protein content was measured using the Kjeldahl method with a Kjeltec 8400 analyzer (FOSS, Hillerød, Denmark). Total fat was quantified via Soxhlet extraction utilizing a Soxtherm® 416 automatic system (Gerhardt, Bonn, Germany). Saturated fat analysis was carried out through gas chromatography using a GC-2010 Plus (Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector (FID) and a capillary column.

Total carbohydrates were calculated by difference, subtracting the sum of protein, fat, moisture, ash, and fiber from the total weight of the sample. The total sugar content was determined using the Luff-Schoorl method, with titrimetric analysis supported by a TitroLine 7000 (SI Analytics, Mainz, Germany). Moisture content was analyzed using a UN55 drying oven (Memmert, Schwabach, Germany) by gravimetric drying at 105°C until a constant weight was reached. Ash content was determined by dry ashing in a Nabertherm LT 40/12 muffle furnace (Nabertherm GmbH, Lilienthal, Germany) at 550°C. Sodium concentration was measured using atomic absorption spectrophotometry with a ContrAA 700 high-resolution AAS (Analytik Jena, Jena, Germany) and appropriate calibration standards.

Total energy and energy derived from fat were calculated using Atwater conversion factors. All procedures followed internal quality control measures and external calibration standards to ensure precision and reproducibility. Results were reported in grams per 100 grams of edible portion and compared to the Indonesian Recommended Dietary Allowances (RDA) and the nutrient content of a comparable commercial chicken nugget product.

### **Data Analysis**

All statistical analyses were conducted using the 2025.05.1+513 version of RStudio (Posit Software, Boston, MA, USA), a widely used open-source environment for statistical computing and graphics. Before analysis, raw datasets were cleaned and converted into analyzable formats to ensure consistency and compatibility across statistical procedures.

A total of 22 variables were analyzed, including the mean and standard deviation values for each sensory attribute across the three formulations. Sensory and nutritional evaluation data were analyzed using one-way Analysis of Variance (ANOVA) to test for significant differences among formulations, followed by Tukey's Honestly Significant Difference (HSD) post hoc tests for pairwise comparisons on each sensory variable.

To assess the impact of catfish-to-tempeh ratios on the nutritional composition of the nuggets, a Multivariate Analysis of Variance (MANOVA) was applied, using macronutrient levels (protein, fat, carbohydrate, etc.) as dependent variables. To validate the MANOVA model and examine interaction effects, a Generalized Linear Model (GLM) framework was employed, ensuring the robustness of the multivariate assumptions.

Finally, Principal Component Analysis (PCA) was conducted to reduce dimensionality and classify related variables into interpretable clusters. The PCA identified two principal components (PC1 and PC2) that collectively accounted for over 78% of the total variance. PC1 represented nutrition-related variables, while PC2 captured variance in sensory attributes. This classification facilitated the simplification of decision-making processes and the identification of the optimal nugget formulation that balances nutritional quality and sensory acceptability.

### 3. RESULTS AND DISCUSSION

#### Results

##### Physical Characteristics of Nulte Nuggets

All three formulations of Nulte nuggets demonstrated visually appealing physical traits intended to enhance children's acceptance (see **Figure 2**). After frying, the nuggets exhibited a uniform golden-brown color and a crispy breadcrumb coating. Internally, the texture was soft yet compact, neither rubbery nor crumbly. Formula 2, which had a higher proportion of catfish, appeared denser than the others. However, all formulations maintained good integrity and an appealing structure. The fishy odor typically associated with catfish was successfully minimized through steaming and the integration of spices, resulting in a savory and appetizing aroma across all samples.



Figure 2. Visual appearance of Nulte nugget formula 1 (A), formula 2 (B), and formula 3 (C).

##### Sensory Evaluation

The sensory evaluation involved 30 untrained panelists (mothers and school-aged children) and assessed five attributes: color, aroma, taste, texture, and overall acceptance. The sensory test scores, using a 5-point hedonic scale, are summarized in Table 2.

Table 2. Summary of sensory test scores of Nulte nugget formulations.

Attribute	Formula 1 (1:1)	Formula 2 (2:1)	Formula 3 (1:2)	Interpretation
Color	4.1 ± 0.5	4.2 ± 0.5	4.1 ± 0.5	Like
Aroma	4.2 ± 0.5	4.0 ± 0.6	3.9 ± 0.6	Like
Taste	4.0 ± 0.6	4.3 ± 0.4	4.0 ± 0.5	Like
Texture	4.1 ± 0.5	4.1 ± 0.5	4.2 ± 0.4	Like
Overall	4.0 ± 0.6	4.2 ± 0.4	4.0 ± 0.5	Like

Although the difference was not statistically significant (see Figure 3), Formula 2 achieved the highest overall acceptance score (4.2), particularly excelling in taste (4.3). This suggests that a 2:1 ratio of catfish to tempeh was the most appealing to the panelists. This formulation appeared to provide the most favorable balance of flavor and texture, critical elements in children's food preferences.

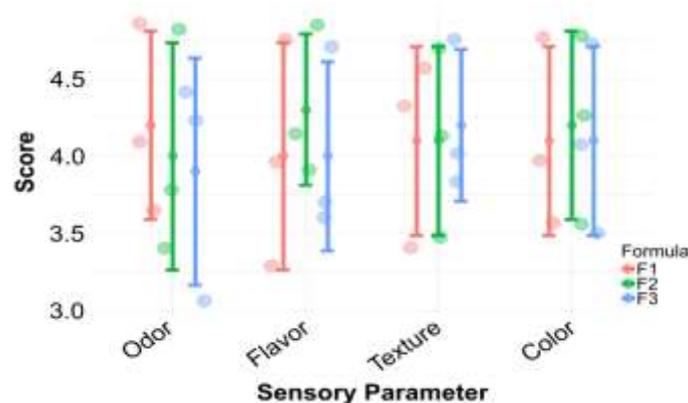


Figure 3. Comparison of sensory scores of Nulte nugget formulations.

The superior acceptability of Formula 2 can be attributed to the dominant presence of catfish, which likely enhanced the umami and savory depth of flavor compared to the other formulas (Liu et al., 2024). Catfish is naturally rich in glutamic acid and fatty compounds that contribute to a more intense meaty taste, which may have made the product more appealing, particularly to children who are sensitive to bland or overly vegetal flavors (Abdel- Mobdy et al., 2021). In terms of color, the higher catfish content resulted in a lighter, more golden interior after frying, which contrasts well with the crisp breadcrumb exterior and visually aligns with familiar commercial nugget products. Texturally, the 2:1 ratio provided a firmer bite and cohesive structure, balancing the tenderness of the fish with the slightly grainy density of the tempeh. This combination likely created a more satisfying mouthfeel without the dryness that can occur when tempeh dominates the formula. Together, these sensory attributes, flavor richness, appetizing color, and pleasing texture, made Formula 2 the most favored by the panelists.

### Nutritional Composition

Proximate analysis revealed variation in nutritional profiles across the three formulations. Formula 2 had the highest protein content at 15.33g per 100g, followed closely by Formula 3 (15.26g), while Formula 1 contained 11.57g. Compared to a commercial chicken nugget product used as a benchmark (11g protein), both Formula 2 and Formula 3 delivered superior protein density. Formula 3 showed the highest fat content (9.39g), while Formula 1 had the highest carbohydrate content (23.16g). The sodium levels in Formulas 2 and 3 (820 mg) were also higher than the commercial reference (580 mg), though still within acceptable dietary limits for children (see Table 3).

Table 3. Macro and micronutrients in Nulte nugget formulations.

Nutrient (per 100g)	Formula 1	Formula 2	Formula 3	Commercial Product
Total Protein (g)	11.57	15.33	15.26	11
Total Fat (g)	7.10	8.79	9.39	12
Saturated Fat (g)	3.44	3.95	4.65	6
Carbohydrates (g)	23.16	20.41	16.72	21
Total Sugar (g)	0	0	0	-
Moisture (g)	56.36	52.63	55.86	-
Ash (g)	1.81	2.84	2.74	-
Sodium (mg)	670	820	820	580
Total Energy (kcal)	200	220	210	230
Energy from Fat (kcal)	60	80	80	-

Based on the ANOVA and Tukey post hoc test results, Formulas 2 and 3 exhibited high levels of total fat and protein, with no statistically significant differences between them (see Figure 4). This indicates that the 2:1 (catfish:tempeh) and 1:2 ratios provided comparable amounts of fat and protein, highlighting both formulations as equivalent sources of these macronutrients. The complementary nutritional profiles of catfish and tempeh may explain this similarity in nutrient content. Catfish is a rich source of complete animal protein and healthy fats, while tempeh, although plant-based, also contains substantial protein and moderate fat due to its fermentation process and soybean content (Arham et al., 2021). In Formula 2, the high protein and fat content was driven primarily by the greater proportion of fish. Meanwhile, in Formula 3, the increased amount of tempeh compensated nutritionally for the reduced fish content, particularly since soybeans are naturally high in protein and contain unsaturated fats. As a result, despite their different compositions, both formulas achieved a nutritional balance that delivered similar overall macronutrient values. This finding highlights the potential of combining animal and plant-based proteins to create nutrient-dense food products that do not rely heavily on a single source of protein.

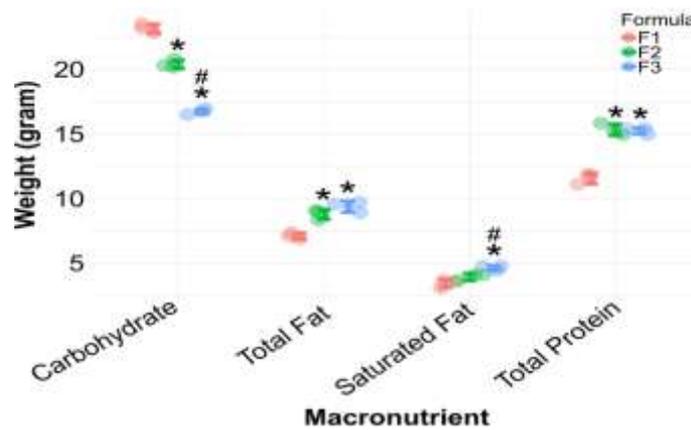


Figure 4. Comparison of macronutrient levels in Nulte nugget formulations.

However, the saturated fat content in Formula 3 was significantly higher compared to the other formulas, while its carbohydrate content was the lowest, also showing a statistically significant difference. This outcome may be attributed to the increased proportion of tempeh in Formula 3. While tempeh is primarily recognized as a plant-based protein, it also contains naturally occurring fats, including saturated fats, mainly when produced from full-fat soybeans (Messina, 2016; Pingali et al., 2023). Additionally, the fermentation process can slightly increase the lipid concentration per gram due to moisture reduction (STEINKRAUS et al., 2006). On the other hand, the lower carbohydrate content in Formula 3 can be attributed to the substitution effect; the inclusion of more tempeh (high in protein and fat) leaves less room for carbohydrate-rich components like flour and starch to contribute proportionally to the overall formulation.

From a stunting prevention perspective, the higher saturated fat content may be a double-edged sword. While fats, including saturated fats in moderate amounts, are essential for energy density and the absorption of fat-soluble vitamins (A, D, E, and K), excessive intake, particularly of saturated fats, is generally not recommended for long-term health (Hooper et al., 2020). However, for undernourished children at risk of stunting, energy-dense foods can play a critical role in improving caloric intake. The low carbohydrate content, while not inherently negative, may limit quick energy supply if not balanced with other carbohydrate sources in the child’s diet.

**Contribution to Recommended Dietary Allowances (RDA)**

The nugget formulations were evaluated for their contribution to the Indonesian RDA for children aged 1–3 and 4–5 years. Formula 2 was the most effective contributor to daily protein intake, providing 76.65% of the RDA for children aged 1–3 and 61.32% for children aged 4–5.

Table 4. Nulte nugget contribution to the recommended dietary allowance.

Nutrient	RDA	% RDA F1	% RDA F2	% RDA F3
Children Aged 1-3 Years				
Protein (20g)	20g	57.85%	76.65%	76.3%
Fat (45g)	45g	15.8%	19.5%	20.9%
Carbohydrates (215g)	215g	10.8%	9.5%	7.8%
Energy (1350 kcal)	1350 kcal	14.8%	16.3%	15.6%
Children Aged 4-5 Years				
Protein (25g)	25g	46.28%	61.32%	61.04%
Fat (50g)	50g	14.2%	17.6%	18.8%
Carbohydrates (220g)	220g	10.5%	9.3%	7.6%
Energy (1400 kcal)	1400 kcal	14.3%	15.7%	15.0%

As shown in Figure 5, the RDA contributions of total fat and protein in Formulas 2 and 3 did not differ significantly for children aged 1–3 and 4–5 years. This finding reflects the nutritional equivalence of the two formulations despite their contrasting catfish-to-tempeh ratios. While Formula 2 contains more catfish (2:1), and Formula 3 contains more tempeh (1:2), both ingredients are rich sources of protein and fat, albeit from different origins. Catfish provides high-quality animal protein, along with a notable amount of fat, including omega-3 fatty acids. In contrast, tempeh offers a plant-based source of protein with a moderate fat content derived from soybeans.

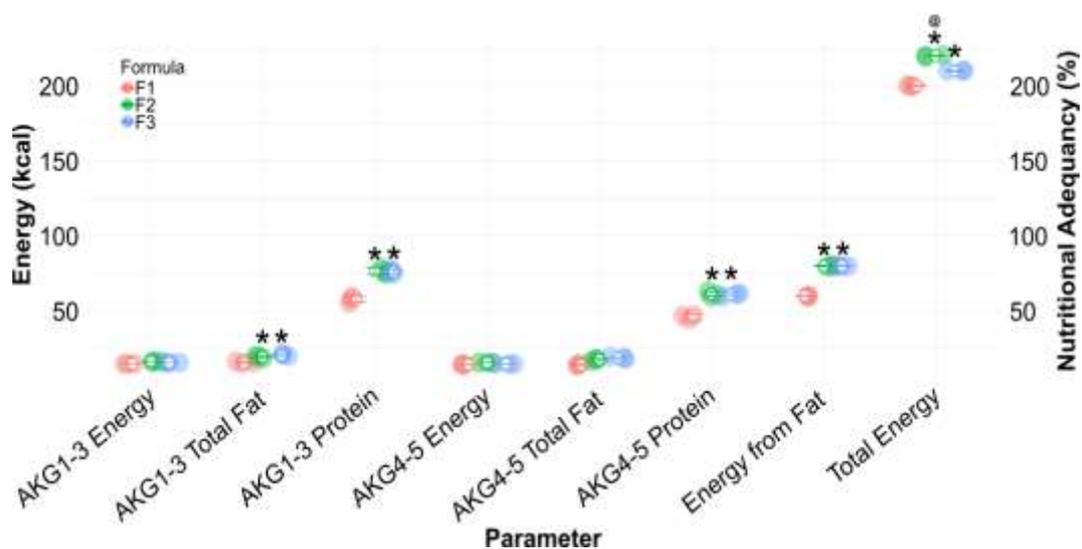


Figure 5. Comparison of Recommended Dietary Allowance (RDA) contribution (%) and total energy content among Nulte nugget formulations. Note: RDA is referred to as AKG in Indonesian. The age ranges (1–3 and 4–5) indicate the corresponding RDA values for children aged 1–3 years and 4–5 years, respectively.

The similarity in RDA contribution between Formulas 2 and 3 likely stems from the complementary nature of their main ingredients. When one protein source was reduced, the other effectively compensated for the loss. Formula 2 relied more on animal protein from catfish, while Formula 3 leaned on the plant-based protein and fats from tempeh. Both ingredients share overlapping macronutrient profiles, particularly in terms of fat and protein density, allowing the formulas to maintain comparable nutritional value when their ratios are adjusted.

While this shows that both versions can effectively meet the protein and fat requirements for child growth, sensory appeal and nutrient bioavailability still give Formula 2 a modest edge. Even so, the comparable RDA profiles offer communities flexibility to choose a formulation based on ingredient access, cost, or dietary preferences without sacrificing nutritional benefits.

One notable distinction in total energy content is that Formula 2 delivered significantly more calories than the others. This difference is tied to its higher catfish content, which brings in more energy-dense macronutrients, especially animal fats and complete proteins (Adi et al., 2025). Given that fat provides 9 kcal per gram and protein 4 kcal, animal-based ingredients naturally raise the caloric density (Espinosa-Salas & Gonzalez-Arias, 2023). Although Formula 3 also showed strong macronutrient levels, its tempeh-forward profile contained less animal fat and more fiber, resulting in a lower overall caloric value. Formula 2's slightly reduced carbohydrate content was more than offset by its higher fat and protein levels, yielding the highest total energy output per 100 grams.

From the perspective of stunting intervention, this energy density is a major strength. Children facing chronic undernutrition require more than just protein; they need sufficient

calories to support weight gain, immunity, cognitive development, and physical activity. For this reason, Formula 2 stands out as the most strategically beneficial option among the three.

### Principal Component Analysis

The PCA analysis yielded two principal components (PC1 and PC2) that explain 78.06% of the total data variation. The first component (PC1) accounts for 64.97% and is strongly associated with protein, fat, and energy variables; thus, it can be interpreted as a dimension representing nutritional quality. Meanwhile, PC2 accounts for 13.10% and is assumed to be related to sensory attributes such as color, aroma, and taste. Therefore, PCA mapping enables the visualization of differences among the formulas based on the combined nutritional and sensory parameters (see Figure 6).

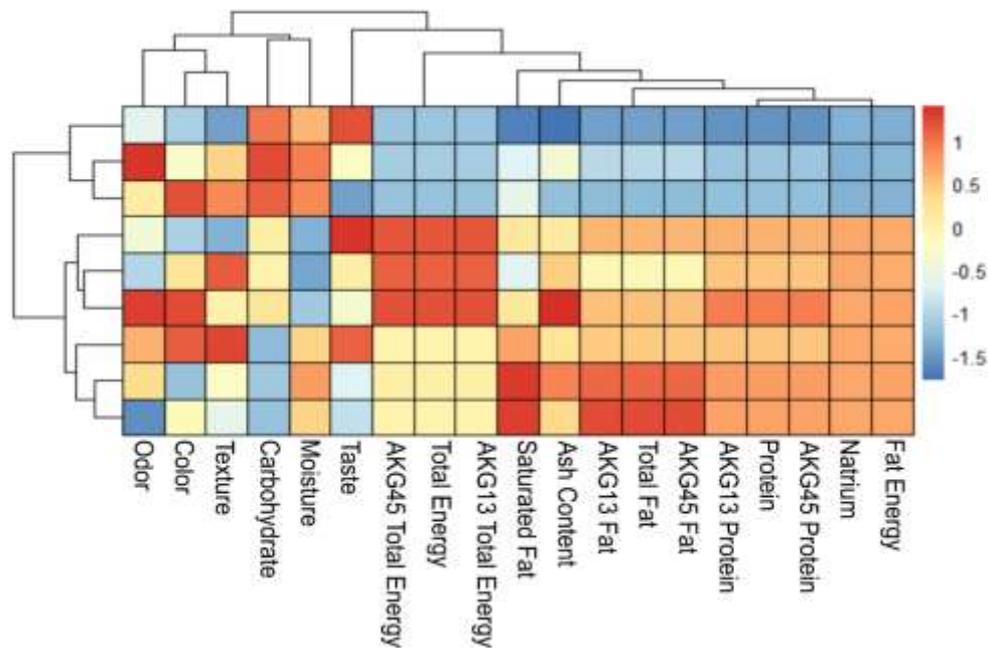


Figure 6. Hierarchical clustering heatmap showing the correlation patterns among sensory attributes and nutritional parameters. Variables are clustered based on similarity, with color intensity representing standardized values (z-scores). Red indicates higher relative values, while blue indicates lower relative values. The clustering reveals distinct groupings between sensory properties (e.g., odor, color, texture) and nutritional components (e.g., protein, fat, energy).

Based on the PCA results, the three formulas occupied distinct regions in the PC1-PC2 coordinate space (see Figure 7). Formula 1 was in the low-PC1 and low-PC2 quadrant, indicating that it performed poorly in nutritional and sensory aspects. In contrast, Formula 2 had high values on both PC1 and PC2, demonstrating strong performance in both nutrient content and sensory acceptability. Meanwhile, Formula 3 scored high on PC1 but low on PC2, suggesting substantial nutritional value but weaker sensory appeal.

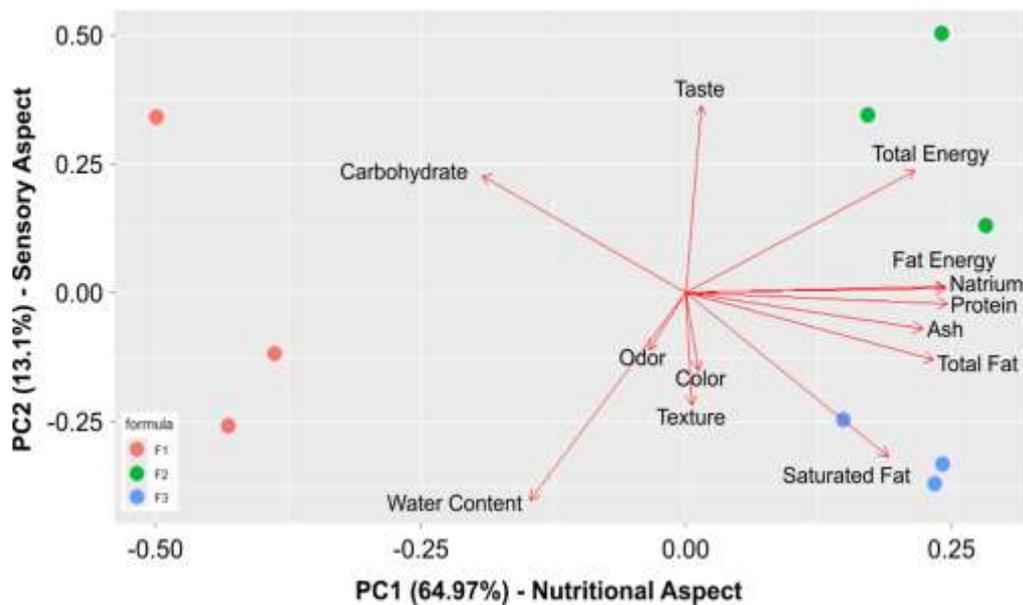


Figure 7. Principal Component Analysis (PCA) of tested variables, identifying two principal components that categorize the strength of each Nulte nugget formulation based on nutritional and sensory aspects.

This outcome is consistent with the earlier findings. PC1 primarily represents nutritional variables such as protein, fat, and total energy. Formula 3 scored high in those areas, especially in saturated fat and protein levels, due to its high tempeh content. Tempeh is a nutrient-dense food, especially in plant-based protein and unsaturated fat, which helps Formula 3 rank high in nutritional performance.

However, PC2 captures sensory attributes like aroma, taste, texture, and overall liking. Formula 3 scored low on PC2 because, despite its good nutrient profile, it was less favored by panelists regarding flavor and aroma. This may be due to the dominant tempeh content, which can introduce a slightly bitter, earthy taste and firmer texture that is less appealing to children (Purwandari et al., 2025). The reduced fish content also likely weakened the savory (umami) intensity that was more prominent in Formula 2. In addition, tempeh's aroma can be polarizing, especially for untrained or younger palates.

In summary, Formula 3's strong nutritional values earned it a high PC1 score; however, its reduced sensory appeal, likely due to flavor and textural imbalances caused by the high tempeh content, pulled down its PC2 score. This highlights the trade-off between nutrient density and acceptability, underscoring the importance of striking a balance between the two to create a functional food product suitable for children.

#### 4. CONCLUSION

In conclusion, this study found that Nulte nuggets, made from a blend of catfish and tempeh, offer a promising, locally sourced solution to support the prevention of stunting in children. Among the three formulations tested, the 2:1 catfish-to-tempeh ratio (Formula 2) stood out as the most balanced, delivering a high protein and energy content while also being the most preferred in terms of taste and texture. Formulas 2 and 3 met significant portions of children's daily nutritional needs. Still, only Formula 2 combined strong nutrient density with broad sensory appeal, making it the most practical option for real-world implementation. This suggests that carefully formulated, child-friendly foods made with local ingredients can play a crucial role in community-level nutrition strategies.

## ACKNOWLEDGE

Our deepest gratitude to the Directorate of Research, Technology, and Community Service (DRPTM) of the Ministry of Education, Culture, Research, and Technology (Kemensaintek) for the funding support through the 2025 community service program with contract number 121/C3/DT.05.00/PM/2025. This support has enabled the implementation of the entire series of community service activities, so that the results of research and innovation can be directly applied to provide real benefits to the community in efforts to prevent stunting.

## REFERENCES

- Abdel- Mobdy, H. E., Abdel-Aal, H. A., Souzan, S. L., & Nassar, A. G. (2021). Nutritional Value of African Catfish (*Clarias gariepinus*) Meat. *Asian Journal of Applied Chemistry Research*, 8(2), 31–39. <https://doi.org/10.9734/ajacr/2021/v8i230190>
- Adi, A. C., Salisa, W., Aulia, N. A. T., Isaura, E. R., Dwirahmadi, F., & Rachmawati, H. (2025). Therapeutic potential effects of catfish and fermented sweet potato chocolate paste on malnutrition in protein-deficient rats. *Discover Food*, 5(1). <https://doi.org/10.1007/s44187-025-00468-6>
- Arham, Z., Kurniawan, K., Anhusadar, L., & Ismaun, I. (2021). Spectroscopic Analysis of Tempeh Protein Content during the Production Process. *International Journal of Transdisciplinary Knowledge*, 2(1), 51–62. <https://doi.org/10.31332/ijtk.v2i1.17>
- Astuti, S. J. W., Suindyah Dwiningwarni, S., & Atmojo, S. (2025). Modeling environmental interactions and collaborative interventions for childhood stunting: A case from Indonesia. *Dialogues in Health*, 6(January), 100206. <https://doi.org/10.1016/j.dialog.2025.100206>
- Bland, J. M., Bett-Garber, K. L., Li, C. H., Brashear, S. S., Lea, J. M., & Bechtel, P. J. (2018). Comparison of sensory and instrumental methods for the analysis of texture of cooked individually quick frozen and fresh-frozen catfish fillets. *Food Science & Nutrition*, 6(6), 1692–1705. <https://doi.org/10.1002/fsn3.737>
- Dewi, P., Khomsan, A., & Dwiriani, C. M. (2024). the Household Food Security and Stunting of Under-Five Children in Indonesia: a Systematic Review. *Media Gizi Indonesia*, 19(1), 17–27. <https://doi.org/10.20473/mgi.v19i1.17-27>
- Espinosa-Salas, S., & Gonzalez-Arias, M. (2023). *Nutrition: Macronutrient Intake, Imbalances, and Interventions*. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK594226/>
- FAO & WHO. (2024). *Sustainable Diets and Local Food Systems for Better Nutrition*. FAO.
- Ghosh, D., & Chattopadhyay, P. (2012). Application of principal component analysis (PCA) as a sensory assessment tool for fermented food products. *Journal of Food Science and Technology*, 49(3), 328–334. <https://doi.org/10.1007/s13197-011-0280-9>
- Hariawan, M. H., Hasanbasri, M., & Arjuna, T. (2024). Stunting and Dietary Diversity in Children 24-59 Months in Indonesia (Analysis of Indonesian Family Life Survey 2014-2015). *Amerta Nutrition*, 8(3SP), 380–389. <https://doi.org/10.20473/amnt.v8i3SP.2024.380-389>
- Hati, E. P., Rum, F. F., & Febriant, N. (2025). Potential of Local Functional Foods for Food Security in Indonesia : A Narrative Review. *Journal of FoodSecure Indonesia*, 1(1), 50–65.
- Hooper, L., Martin, N., Jimoh, O. F., Kirk, C., Foster, E., & Abdelhamid, A. S. (2020). Reduction in saturated fat intake for cardiovascular disease. *The Cochrane Database of Systematic Reviews*, 5(5), CD011737. <https://doi.org/10.1002/14651858.CD011737.pub2>
- Idam, O. A., & Degais, A. I. (2025). Effect of Water Quality Parameters on Nutritive Value of Catfish, Khartoum State, Sudan. *International Journal of Multidisciplinary Research and Growth Evaluation.*, 6(2), 666–672. <https://doi.org/10.54660/ijmrge.2025.6.2.666-672>
- Indriyani, R., Novika, Y., Lupiana, M., & Wahyuni, E. S. (2023). Study of Tortilla Chips Snack from Corn Flour and Tempeh Formulation for Stunting Prevention. *Amerta Nutrition*, 7(3), 358–364. <https://doi.org/10.20473/amnt.v7i3.2023.358-364>
- Kementrian Kesehatan RI. (2024). *Survei Status Gizi Indonesia 2025*. Kementerian Kesehatan RI.

- Kustyawati, M. E., Pratama, F., Saputra, D., & Wijaya, A. (2020). Shelf life of tempeh processed with sub-supercritical carbon dioxides. *Potravinarstvo Slovak Journal of Food Sciences*, 14(June), 351–357. <https://doi.org/10.5219/1247>
- Liu, Z., Wei, S., Xiao, N., Liu, Y., Sun, Q., Zhang, B., Ji, H., Cao, H., & Liu, S. (2024). Insight into the correlation of key taste substances and key volatile substances from shrimp heads at different temperatures. *Food Chemistry*, 450, 139150. <https://doi.org/10.1016/j.foodchem.2024.139150>
- Messina, M. (2016). Soy and Health Update: Evaluation of the Clinical and Epidemiologic Literature. *Nutrients*, 8(12). <https://doi.org/10.3390/nu8120754>
- Patmawati, Trilaksani, W., Zahidrudin, W., Fatmaningrum, W., & Nadhiroh, S. R. (2022). Diversification of local products based on Wet Protein Isolate of Catfish (*Clarias Sp*) as a protein source to prevent stunting. *Media Gizi Indonesia*, 17(1SP), 6–12. <https://doi.org/10.20473/mgi.v17i1SP.6-12>
- Pingali, P., Boiteau, J., Choudhry, A., & Hall, A. (2023). Making meat and milk from plants: A review of plant-based food for human and planetary health. *World Development*, 170, 106316. <https://doi.org/10.1016/j.worlddev.2023.106316>
- Prameswari, N. A., Prawesti, M. S., Astuti, S. D., Yapita, J., Helmyati, S., Rosilia, G., Aristyarini, M., Sitorus, N. L., & Pratiwi, D. (2023). Public Search Interest in Stunting Interventions as an Effort to Reduce the Incidence of Stunting in Indonesia during 2018-2022: A Google Trends Analysis. *Amerta Nutrition*, 7(3SP), 41–49. <https://doi.org/10.20473/amnt.v7i3SP.2023.41-49>
- Purwandari, U., Hidayati, D., Rahman, A., Nurhidayah, E. S., Purwantini, I., Prasetya, E. C., Nurhayati, N., Pujimulyani, D., Jayus, J., Ruriani, E., Suswati, E., Arimurti, S., Suryani, C. L., Kanetro, B., & Setiarto, R. H. B. (2025). Exploring the profile of amino acids and ethnography study in the biodiversity of tempeh as fermented foods of Indonesia. *Journal of Ethnic Foods*, 12(1). <https://doi.org/10.1186/s42779-025-00285-3>
- Rizzo, G. (2024). Soy-Based Tempeh as a Functional Food: Evidence for Human Health and Future Perspective. *Frontiers in Bioscience (Elite Edition)*, 16(1), 3. <https://doi.org/10.31083/j.fbe1601003>
- Shadyeva, L., Romanova, E., Romanov, V., Spirina, E., Lyubomirova, V., Shlenkina, T., & Fatkudinova, Y. (2019). Forecast of the nutritional value of catfish (*Clarias gariepinus*) in the spawning period. *IOP Conference Series: Earth and Environmental Science*, 403(1). <https://doi.org/10.1088/1755-1315/403/1/012218>
- Sihombing, F., Rumaseuw, E. S., & Raniadita, M. A. (2024). Analysis of the Nutritional Content of Catfish Extract as a Reliable Food Ingredient to Improve the Nutrition of Stunted Toddlers. *Jurnal Biologi Tropis*, 24(3), 216–222. <https://doi.org/10.29303/jbt.v24i3.7335>
- STEINKRAUS, K., HWA, Y. A. P., Buren, J., PROVVIDENTI, M., & HAND, D. (2006). Studies on tempeh – An Indonesian Fermented soybean food. *Journal of Food Science*, 25, 777–788. <https://doi.org/10.1111/j.1365-2621.1960.tb00026.x>
- Syitra, S. M. L. P., Tiara, A., & Tarigan, A. A. (2025). Effectiveness of Community-Based Nutrition Interventions in Preventing Stunting and Malnutrition in Toddlers: A Literature Review. *International Journal Of Health Science*, 5(2), 78–88. <https://doi.org/10.55606/ijhs.v5i2.5252>
- Teoh, S. Q., Chin, N. L., Chong, C. W., Ripen, A. M., How, S., & Lim, J. J. L. (2024). A review on health benefits and processing of tempeh with outlines on its functional microbes. *Future Foods*, 9(March), 100330. <https://doi.org/10.1016/j.fufo.2024.100330>
- Tucker, C. S., & Schrader, K. K. (2020). Off-flavors in pond-grown ictalurid catfish: Causes and management options. *Journal of the World Aquaculture Society*, 51(1), 7–92. <https://doi.org/10.1111/jwas.12672>
- UNICEF, WHO, & World Bank. (2023). *Levels and trends in child malnutrition*.
- Utami, N. D., & Iwan, S. (2025). *Acceptability of Catfish Nugget in Toddler Integrated Health Service Post (Posyandu) of Dermo Subdistrict, Mojoroto District, Kediri City*. 10(1), 42–46.
- Veronica, W., & Siregar, A. (2022). Acceptance of High Protein Nuggets as an Animal Side Dish for Toddlers Wasting. *Prime Nutrition Journal*, 7(2), 101–106.

- Werdiningsih, B., Musviro, Sulistyawati, A., & Ulin Tarisa, A. (2023). Tempeh Nuggets as an Additional Feeding Intervention to Prevent Stunting in Padang Village, Lumajang. *Journal of Community Empowerment for Multidisciplinary (JCEMTY)*, 1(2), 125–132. <https://doi.org/10.53713/jcemty.v1i2.110>
- Wittman, H. (2023). Food sovereignty: An inclusive model for feeding the world and cooling the planet. *One Earth*, 6(5), 474–478. <https://doi.org/10.1016/j.oneear.2023.04.011>
- Yanti, E. S., Imami, R., & Arica, A. (2024). Raising Awareness of the Impact of Stunting on Toddler Development Through Parental Education. *Amalee: Indonesian Journal of Community Research and Engagement*, 5(2), 751–764. <https://doi.org/10.37680/amalee.v5i2.5850>