



Nutritional Assessment of Sagurimi: Innovative Dry Noodles from Sago Flour and Nile Tilapia (*Oreochromis niloticus*) for Stunted Children

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Abstract—Chronic malnutrition at crucial stages of a child's development can result in stunting, a serious public health concern. The goal of this study was to create high-protein dry noodles. The study used several methods, such as the oven method for measuring water content, the dry ashing method for ash, the Soxhlet method for fat, the Kjeldahl method for protein, the difference method for carbohydrates, the enzymatic method for fiber, the Atwater factor for energy content, the Na₂EDTA complexometric titration for calcium, the atomic absorption spectroscopy (AAS) for iron, the in vitro method for measuring protein digestibility, and the DPPH method for measuring antioxidants. Three formulations, namely F1 (20:20:60), F2 (30:40:30), and F3 (40:30:30), were developed to represent different ratios of sago flour, wheat flour, and fish meal. F1 exhibited the highest nutritional values, particularly in protein (24.60 g), fat (29.19 g), calcium (479.57 mg), iron (26.11 mg), and antioxidant activity (35.79%). The best formulation was selected using the Index of Effectiveness method, combining rankings of nutrient content and sensory acceptability. Due to its higher wheat flour content, F2 had the highest calorie content (494.04 kcal) and carbohydrate content (33.24 g). Because F3 contained more sago flour, it had the most fiber (14.98 g). These results demonstrate the potential to create novel, regionally sourced foods, such as Sagurimi made from Nile tilapia, to help reduce childhood stunting. To evaluate acceptability and efficacy, future research should focus on clinical trials and sensory evaluation.

Keywords—Dry Noodle; High Protein; Stunted; Supplementary Food

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I. INTRODUCTION

Stunting is still a significant public health problem, especially in developing countries like Indonesia. According to the Indonesian Nutritional Status Study (SSGI), the prevalence of stunting in 2021 was 24.4%. [1] Comparison of data from the 2018 Riskesdas and 2019 SSGI showed a decrease, but the highest stunting age group shifted from 37.3% of stunted children aged 12-23 months to 34.65% aged 24-35 months. [2] Stunting is caused by chronic malnutrition during the critical growth period and can inhibit children's cognitive and physical

development. [3] One of the main strategies for addressing stunting is to provide additional foods rich in essential nutrients, especially protein, iron (Fe), calcium (Ca), and dietary fiber. [4]

In 2020, the Directorate of Community Nutrition of the Ministry of Health explained that the main factor in stunting is the lack of community access to nutritious food. However, in the community, children have difficulty consuming protein sources and prefer low-nutrient snack products, such as extruded snacks. In fact, at that age, children really need

protein for growth and development.[5] Therefore, the food innovation to be developed is high-protein dry noodles as an additional food for stunted children.

This product innovation is in the form of high-protein dry noodles that utilize local foods, namely sago flour and Nile Tilapia fish meal. The selection of these two ingredients is based on the results of several preliminary studies that previously failed or produced an unacceptable texture. The combination of sago flour and Nile Tilapia fish meal was chosen because it produces a dry noodle texture, unlike cornstarch, fish protein hydrolysate flour, or wheat flour. In addition, this combination also produces a more optimal taste, color, aroma, and nutritional value, especially in terms of protein content. Unlike conventional fortified noodles, Sagurimi was developed using a distinct approach that combines sago flour with Nile tilapia fish meal as a protein fortificant and is processed using a noodle maker to optimize the use of local food resources.

Sago flour in 100 grams includes 353 calories, 0.7 grams of protein, 0.2 grams of fat, 84.7 grams of carbs, 11 mg of calcium, and 1.5 mg of iron.[6] Meanwhile, Nile Tilapia fish has 128 calories, 26 grams of protein, and 3 grams of fat.[7, 8] The combination of these two indigenous foods functions as a source of carbs and protein in an extra diet for stunted children. The product optimization stage involves examining physicochemical, organoleptic, and shelf-life quality. 222.32 calories, or approximately 18.5% of the child's energy requirements, are provided by every 45 grams of this product, which is given as additional food.

Additional food given to stunted children is not only highly nutritious but also has a good taste, is easy to accept, practical to serve, and easy to distribute widely.[9] Among the meal choices, dry noodles are a preferred option because they have a long shelf life, are easy to store, and are popular with children. Furthermore, dry noodles enable food to be distributed more widely, even to isolated locations with limited access to wholesome food. A new product called Sagurimi, high-protein dry noodles made from sago flour and Nile Tilapia as a source of high-quality protein, was created to address the nutritional needs of stunted children.

Similar research on maize flour and fish protein hydrolysate (Mizepi) has also been conducted under emergency food conditions, with high protein content, for vulnerable groups such as children.[10] Another study found that the F2 formulation (25:15 winged bean seed flour to cassava leaf paste) produced the most preferred biscuits in organoleptic tests, and that the potential exists to utilize local agricultural resources to develop nutritious, affordable, and stunting-preventive food products.[11] Research on fish supplementation indicates that the program in Serdang Bedagai Regency successfully reduced stunting prevalence by 37.00% over six months, with the most significant improvements observed among children receiving locally produced fish-

based supplements, highlighting their effectiveness in improving HAZ and WHZ scores and addressing childhood malnutrition.[12]

Analyze nutrition, including nutritional value, carbohydrates, protein, fat, ash, water content, protein digestibility, dietary fiber, iron, calcium, and antioxidants. Sagurimi targets children aged 3-5 years who experience stunting, aiming to offer a functional food product grounded in science that improves nutritional intake and health status. The results of this study are expected to be the basis for further development and implementation of nutritious additional foods to reduce stunting rates in Indonesia and other countries with similar problems

II. MATERIAL AND METHODS

A. Materials

Sagurimi formulations containing sago flour, wheat flour, and Nile Tilapia (*Oreochromis niloticus*) flour, in gram units, are F1 (20:20:60), F2 (30:40:30), and F3 (40:30:30). A completely randomised design was used to determine the comparative ratios for these formulations.

B. Sagurimi Making Process

All the elements were combined to make sagurimi, beginning with the dry ingredients (sago flour, wheat flour, Nile Tilapia (*Oreochromis niloticus*) flour, and salt). After that, the mixture was thoroughly combined with the utilised Oxone 537 large noodle maker before the wet ingredients (water and coconut oil) were added. After that, put all the ingredients into the noodle maker tool, close it with the proper sensor, and press the rapid noodle button to start mixing. To accurately watch the water droplets, add water through the glass that comes with the noodle maker. Once all the components have been combined, push the elastic noodle button to make the dough more elastic. Continue mixing until the tool's allotted time has passed, if the dough is judged sufficient. Until the dough is ready to be shaped into noodles, keep kneading it by choosing the knead dough option to increase its elasticity. The sagurimi was then cooked at 110 °C for 35 minutes and fried at 140 °C for 60 seconds.

C. Analysis of Sagurimi

Water content analysis.

Determination of water content using the oven method. The principle of water content analysis using the oven method or thermogravimetry is to evaporate water in the material by drying and weighing it until a constant weight is reached (as much water as possible has been evaporated). The tools used are porcelain cups, cup clamps, desiccators, ovens, and analytical scales. The materials used are Sagurimi samples. The working procedure is first to weigh 3 grams of sample and put it in a porcelain cup that has been dried and its weight is known; dry the sample in an oven at a temperature of 105 °C for 6 hours; remove the cup from the oven and cool it in a

desiccator for 15 minutes, then weigh it (the drying and weighing process is carried out until it reaches a constant weight.[13] The water content is obtained from the calculation:

$$\text{Water Content (\%)} = \frac{\text{initial weight (g)} - \text{final weight (g)}}{\text{initial weight (g)}} \times 100\% \quad \text{eq (1)}$$

Ash content analysis

Determination of ash content using the dry ashing method. The principle of this method is that, during ashing, organic substances are broken down into water and carbon dioxide, whereas inorganic materials are not. These inorganic substances are called ash. The tools used are porcelain cups, cup clamps, desiccators, ovens, furnaces, electric stoves, and analytical scales. The materials used are Sagurimi samples. The working procedure is to prepare a porcelain cup, then dry the empty cup in an oven at 105 °C for 30 minutes. Then cool in a desiccator (30 minutes) and weigh; Weigh 5 grams of sample into a porcelain cup; Burn the cup on an electric stove until it is smoke-free and put it in an ashing furnace at a temperature of 600 °C until ashing is complete for 7 hours; Cool in a desiccator, then weigh until constant weight.[13] The ash content is obtained from the calculation:

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

Information:

A = weight of empty cup (grams)

B = weight of cup with sample (grams)

C = weight of cup with sample after drying (grams)

Fat Content Analysis

Fat content was determined using the Soxhlet method. Soxhlet extraction is a heating-based extraction method. The selection of solvents is important for determining fat content using the Soxhlet method. Research shows that hexane is more efficient than other solvents, and the optimal extraction time is 3 hours with the selected solvent.

The tools used are filter paper, a Soxhlet extraction tube, a Soxhlet extraction apparatus, a condenser, a fat flask, an oven, a desiccator, and an analytical balance. The materials used are hexane solvent and water. The working procedure is to weigh 2 grams of the ground and wrapped Mi sample. Insert the sample into the Soxhlet extraction tube, which is assembled with a condenser. Pair the extraction tube with the weighed fat flask containing the solvent in the Soxhlet distillation apparatus. Then flow water as a coolant and turn on the tool (extraction is carried out for 3 hours); Evaporate the solvent by drying the fat flask in an oven at a temperature of 105 °C for 30 minutes to separate the solvent from the fat; Cool the fat flask in a desiccator until it reaches constant weight; The weight of the residue in the fat flask is expressed as the weight of fat or oil.[13] The fat content is obtained from the calculation:

$$\text{Fat Content (\%)} = \frac{\text{fat weight (g)}}{\text{sample weight (g)}} \times 100\% \quad \text{eq (3)}$$

Protein Analysis

Protein content is determined using the Kjeldahl method. The principle of this method is to determine protein by oxidizing carbon materials and converting nitrogen into ammonia. After that, ammonia reacts with excess acid to form ammonium sulfate. Ammonia is evaporated after the solution becomes alkaline, allowing it to be absorbed by the boric acid solution. HCl titration is used to determine the amount of nitrogen present. The protein content analysis procedure using the Kjeldahl method consists of 3 stages, namely destruction, distillation, and titration. The tools used are a destruction flask, a destruction tool, a distillation tool, an Erlenmeyer flask, a burette, a measuring cup, and an analytical balance. The materials used are Sagurimi sample; K₂SO₄; CuSO₄; concentrated H₂SO₄; distilled water; NaOH 45%; H₃BO₃ 4%; HCl 0.1 N. The working procedure starts from the destruction stage, namely Weighing the mashed sample as much as 1 gram and putting it into the destruction flask; Adding 5 grams of K₂SO₄, 0.5 grams of CuSO₄, and 15 ml of concentrated H₂SO₄ in the destruction flask, then shaking the solution until mixed and letting it stand for 5 minutes; Placing the destruction flask containing the solution on the destruction tool and the destruction process is carried out for 3 hours (until the solution becomes clear); Cooling the destruction results, then adding 25 ml of distilled water. Next, add 20 ml of 45% NaOH, then carry out the distillation. Collect the distillation products in a 125 ml Erlenmeyer flask containing 25 ml of 4% H₃BO₃ (boric acid) solution. The last step is the titration stage: start by taking the distillation results, then titrate with 0.1 N HCl until the solution in the Erlenmeyer turns pink, read and record the titration volume, and determine the blank in the same way without using a sample.[13] Protein levels are obtained from calculations:

$$\% \text{ Nitrogen} = \frac{(V \text{ HCl sample} - V \text{ HCl blanko}) \times N \text{ HCl} \times 14}{\text{sample weight (mg)}} \quad \text{eq (4)}$$

Protein content (%) = % Nitrogen x conversion factor (6.25)

Description:

V = Volume (ml)

N = Normality (N)

Carbohydrate Analysis

Determination of carbohydrate content using the by difference method, which is the result of subtracting 100% with water content, ash content, protein content, and fat content, so that the carbohydrate content depends on the reduction factor. The following is an equation for calculating carbohydrate content using the difference method:[13]

$$\text{Carbohydrate content (\%)} = 100\% - (\% \text{ water content} + \% \text{ ash content} + \% \text{ protein content} + \% \text{ fat content}) \quad \text{eq (5)}$$

Energy Content Analysis

Energy content is determined by manual calculations using the Atwater factor. The Atwater factor states that 1 gram of carbohydrates produces 4 kcal of energy, 1 gram of protein

produces 4 kcal of energy, and 1 gram of fat produces 9 kcal of energy.

Total Fiber Content Analysis

The dietary fiber test can be performed by placing 0.5 grams of the sample into an Erlenmeyer flask. Next, 0.1 ml of alpha-amylase enzyme is added; this enzyme cleaves the O-glycosidic bond of amylose or amylopectin chains. Then heated in a water bath at 100 °C for 15 minutes, stirring occasionally. The sample is removed and cooled, then 20 ml of distilled water is added, followed by 5 ml of 1 N HCl. Furthermore, 1% pepsin enzyme, up to 1 ml, is added to the Erlenmeyer containing the sample; this enzyme functions as a protein cutter. Then heated in a water bath for 1 hour. After that, the Erlenmeyer is removed, and 5 ml of 1 N NaOH is added, and 0.1 ml of beta amylase enzyme is added to the Erlenmeyer. The Erlenmeyer flask was then closed, incubated in a water bath for 1 hour, and filtered onto a weighed filter paper. Furthermore, the sample was washed with ethanol and acetone (10 ml each) 2 times. The sample was then dried in an oven at 105 °C for 1 night, cooled in a desiccator, and weighed to obtain the final weight (insoluble dietary fiber). The filtrate volume was then adjusted to 100 ml, and 400 ml of warm 95% ethanol was added. The filtrate was allowed to settle for 1 hour, then filtered with ash-free filter paper, then washed again with ethanol and acetone as in the treatment above. Then dried overnight in an oven at 105 °C. Then place in a desiccator and weigh to obtain the final weight (soluble dietary fiber). The content of dietary fiber can be calculated using the formula:[13, 14]

$$\text{Total Dietary Fiber} = \text{soluble dietary fiber} + \text{insoluble dietary fiber} \quad \text{eq (6)}$$

Analysis of Antioxidant Content

The analysis of antioxidant content is carried out in several stages. The first stage is preparing a 0.1 mM DPPH solution. DPPH powder with a molecular weight of 394.32 was weighed to 0.39432 grams and dissolved in 10 ml of methanol p.a. Then, 100 µl of the 0.1M DPPH solution was pipetted into a 100 ml volumetric flask and diluted with methanol p.a. to the mark, resulting in a 0.1 mM DPPH solution.

Next, the maximum wavelength of DPPH is determined. A total of 2 ml of the 0.1 mM DPPH solution was placed in a test tube, and 2 ml of methanol p.a. was added. The mixture was vortexed until homogeneous, then transferred to a cuvette and measured using a UV-Vis spectrophotometer within a wavelength range of 400-800 nm. The maximum wavelength obtained was 517 nm.

The preparation of a blank solution follows. A total of 2 ml of a 0.15 mM DPPH solution was placed in a test tube, and 2 ml of methanol p.a. was added. The solution was vortexed until homogeneous and incubated in a dark room for 30 minutes before measuring its absorbance at a wavelength of 517 nm.

The next step is to prepare a 1000 ppm extract master solution. The sample was dissolved in methanol p.a., placed in a 100 ml volumetric flask, and diluted with methanol p.a. to the mark. Absorbance is then measured using a UV-Vis spectrophotometer. A total of 2 ml of each test solution concentration was placed in a test tube, followed by the addition of 2 ml of a 0.1 mM DPPH solution. The mixture was vortexed for 30 minutes before measuring its absorbance at a wavelength of 517 nm.

The percentage of inhibition is then determined. The radical scavenging activity is expressed as percent inhibition, which is calculated using the formula:[13, 15]

$$\% \text{ Inhibition} = \frac{\text{Blank absorbance} - \text{sample absorbance}}{\text{Blank absorbance}} \times 100 \quad \text{eq (7)}$$

Finally, the IC50 value is determined. Antioxidant activity analysis using the DPPH method is based on the color change observed in each sample after incubation with DPPH. If all the DPPH electrons pair with the electrons in the sample extract, the sample color changes from dark purple to bright yellow. The absorbance value of the sample is then measured using a UV-Vis spectrophotometer at a wavelength of 517 nm.

Calcium Content Analysis

Standardization of the Na₂EDTA solution was performed by titrating 220 mg of ZnSO₄ · 7H₂O to which 25 mL of aquabides and 5 mL of ammonium chloride buffer pH 10 have been added. The addition of 1% (w/w) Eriochrome Black T (EBT) indicator of 50 mg is carried out when the titration begins. The endpoint of the titration is marked by a color change from purplish red to blue. Standardization of the Na₂EDTA solution was carried out three times. Determination of the molarity of Na₂EDTA follows the equation:

$$M = \frac{m}{Mr} \times \frac{1}{v} \quad \text{eq (8)}$$

Information :

- M = Molarity of Na₂EDTA (M)
- m = Mass of ZnSO₄ · 7H₂O (mg)
- Mr = Relative molecules ZnSO₄ · 7H₂O
- V = Volume Na₂EDTA (mL)

Next, a total of 4 mL of the fresh milk sample was pipetted into an Erlenmeyer flask, and 100 mL of aquabides was added. The pH of the solution to be titrated is adjusted to pH 12-13 by adding 2 N NaOH. The addition of 50 mg of 0.2% (w/w) murexide indicator is carried out when the titration begins. Titration was carried out with a standardized 0.050 M Na₂EDTA solution. The endpoint of the titration is marked by a color change from pink to purple.[13, 14] Determination of calcium levels in fresh milk follows the following equation:

$$\text{Calcium levels (mg/100ml)} = \frac{M \times V_1 \times 40,08 \times 100}{V_2} \quad \text{eq (9)}$$

Information :

- M = Molarity Na₂EDTA (M)

V_1 = Volume Na_2EDTA (mL)
 V_2 = Sample volume (mL)

Iron Content Analysis

Each standard Fe solution was injected into the SSA tool at concentrations of 0 ppm, 5 ppm, 10 ppm, 20 ppm, and 50 ppm. Then measure the absorbance at a wavelength of 283.3 nm. Furthermore, the measurement results were recorded, and a calibration curve was made to obtain the linear equation.[14]

Vitamin C Content Analysis

Analysis of vitamin C levels was performed by preparing a standard curve of ascorbic acid at concentrations of 2 ppm, 4 ppm, 6 ppm, 8 ppm, and 10 ppm. The standard curve solution was analyzed using a UV-Vis spectrophotometer with a wavelength of 260 nm. Furthermore, a sample of 10 mg of noodle extract was analyzed using a UV-Vis spectrophotometer with a wavelength of 260 nm to determine the level of vitamin C contained in the noodle extract.[13, 14]

Protein Digestibility Test

Protein digestibility was analyzed in vitro by measuring the decrease in pH after the hydrolysis reaction. Sagurimi noodles from three formulations (F1, F2, and F3) were dried and ground into powder. Casein solution served as the standard. A total of 0.5 g of each powdered sample was used in duplicate, mixed with 30 mL of distilled water (pH 8.0), and homogenized. From this mixture, 20 mL was taken for treatment; its initial pH was recorded, then divided into two portions: one as a blank and the other treated with 1 mL of enzyme solution. Both samples were incubated at 37 °C for 10 minutes. After incubation, pH was remeasured, and 2 mL of the mixture was transferred to a test tube, then 4 mL of 0.1 M TCA was added, vortexed, and centrifuged at 3500 rpm for 10 minutes. The resulting supernatant (1.5 mL) was mixed with 5 mL of Na_2CO_3 and 1 mL of Folin reagent, incubated at 37 °C for 20 minutes, and the absorbance was measured at 578 nm using a spectrophotometer.[13]

D. Data Analysis

The best formulation was determined using an index of effectiveness (Index of Effectiveness) scoring method, which ranked each formulation based on multiple parameters, including the highest nutrient contents and the most favorable sensory acceptance by panelists. This study has received ethical clearance approval from the Health Research Ethics Committee, Faculty of Medicine, Diponegoro University, under approval number 003-EC/KEPK/FK-UNDIP/I/2025. Based on the chemical composition analysis of the three product formulations with varying ratios of sago flour, wheat flour, and fish meal F1 (20:20:60), F2 (30:40:30), and F3 (40:30:30), significant differences were observed in several proximate parameters and nutritional components among the formulations. Bivariate analysis was performed using a one-

way ANOVA, and variables that showed significant differences were further analyzed using the LSD post hoc test.

III. RESULT AND DISCUSSION

Chemical composition analysis of the three formulations, F1 (20:20:60), F2 (30:40:30), and F3 (40:30:30), revealed significant differences in several proximate and nutritional parameters (Table 1). The highest carbohydrate content is in F2, followed by F1, while F3 has the lowest. The carbohydrate content increases with the proportion of wheat flour.[16, 17] F1 exhibited the highest protein content, followed by F3 and F2. Fat content was also highest in F1, not significantly different from F2, while F3 showed the lowest value. In general, both protein and fat contents increased with a higher proportion of Nile tilapia fish meal in the formulation.[18, 19]

TABLE 1
 RESULTS OF SAGURIMI CONTENT ANALYSIS IN FORMULAS
 F1, F2, AND F3

Proximate and Macro-nutrient Composition	F1	F2	F3	p
Water content*	11.58±0.52 ^a	11.41±0.2 ^{1b}	11.69±0.47 ^c	0.001
Ash content*	1.39±0.07 ^a	1.09±0.09 ^{ab}	1.23±0.42 ^c	0.001
Carbohydrate**	33.24±0.07 ^a	41.44±0.3 ^{9b}	15.72±0.14 ^c	0.001
Protein**	24.60±0.49 ^a	18.28±0.0 ^{7b}	21.56±0.55 ^c	0.001
Fat**	29.19±0.82 ^a	27.78±0.0 ^{7a}	21.56±0.55 ^b	0.001
Insoluble dietary fiber**	11.12±0.82 ^a	9.78±0.41 ^b	9.86±0.2 ^a	0.001
Soluble dietary fiber**	1.13±0.02 ^a	0.62±0.16 ^b	0.65±0.07 ^a	0.001
Protein Digestibility**	21.19±0.05 ^a	18.08±0.2 ^{8b}	19.83±0.22 ^c	0.001
Antioxidant*	35.79±0.45 ^a	29.37±0.4 ^{8a}	32.5±0.54 ^c	0.001
Calcium**	479.57±0.5 ^{1a}	456.13±0.03 ^a	460.38±0.84 ^c	0.001
Iron*	26.11±0.82 ^a	24.9±0.59 ^b	25.83±0.74 ^c	0.001
Dietary Fiber**	10.49±0.52 ^a	10.91±0.7 ^{3a}	14.98±0.00 ^b	0.001
Energy**	494.04±0.8 ^{1a}	488.93±0.82 ^b	456.28±0.52 ^c	0.001

Description: product formula of sago flour: wheat flour: fish meal (grams) is F1 (20: 20: 60), F2 (30: 40: 30), F3 (40: 30: 30). Numbers followed by different superscripts such as (a, b, c) indicate a significant difference in each type of amino acid content. n = 9 (3 experiments _ 3 repetitions). Data are presented in the form of mean and standard deviation.

* One-Way Anova

** One-Way Anova continued with the LSD test

F1 had the highest levels of both insoluble and soluble dietary fiber. The total dietary fiber content showed that F3 had the highest content, followed by F2 and F1. The highest antioxidant content was found in F1, while F2 had the lowest antioxidant content. F1 had the highest calcium and energy contents, while F3 contained the most iron. Protein digestibility was also excellent in F1, followed by F3 and F2. These variations indicate that the proportions of sago flour, wheat flour, and fish meal markedly affected the chemical composition and functional properties of the product.

The results showed that the F1 formulation contained the highest levels of protein, fat, calcium, and antioxidants, making it the best formulation for developing nutrient-dense food for stunted children (**Figure 1**). This superiority is attributed to the higher proportion of Nile tilapia fish meal in F1. Fish meal is naturally rich in high-quality protein, essential fatty acids, and key minerals such as calcium and phosphorus, which are important for bone growth and brain development in children.[20, 21] In addition, tilapia contains antioxidant compounds such as selenium and omega-3 fatty acids that play a role in improving the immune system and cellular health.[22]



Product of Sagurimi

Sagurimi and Packaging

Packaging of Sagurimi

Fig. 1 Result of Sagurimi product
Source: Authors' documentation, 2025.

Formulation F2 has the highest carbohydrate content because it uses more wheat flour. In addition, wheat flour contains gluten protein, but at lower levels than fishmeal [23], which explains why the protein content of F2 is lower than that of F1. Scientifically, studies have shown that fishmeal can increase protein levels in food formulations due to its high content of essential amino acids. At the same time, wheat flour supports more rapid energy through carbohydrate metabolism.[24] The combination of the two can be adjusted to meet specific nutritional needs, especially for children at risk of stunting or high energy needs.

Significant differences in proximate parameters indicate that the selection of raw materials affects the product's nutritional quality. As previous research explains, the use of locally sourced, high-protein ingredients, such as fish, can significantly improve the nutritional status of stunted children [25]. The study found that six months of fish-based supplementation in Serdang Bedagai Regency reduced stunting prevalence by 37% [26].

A similar study on the development of local resource-based food. They found that mixing food ingredients like fishmeal and local starch can make products healthier and more appealing to kids.[27] Their research into making biscuits from cassava leaf and cowpea seed formulations to prevent stunting.[11] This is in line with the results of research on Sagurimi, namely, that the combination of sago flour and tilapia fish meal can increase the protein, dietary fiber, and iron content of the product.

F1 exhibited the highest protein digestibility, whereas F2 and F3 demonstrated lower digestibility. The protein digestibility in this study is also consistent with previous research, which found that fish protein-based products have higher protein digestibility than vegetable protein sources.[28] The results showed that the F1 formulation had the highest protein digestibility (21.19%). This suggests that the ingredient mix in Sagurimi products can help stunted children increase their protein intake.

Several factors influence the digestibility of proteins in fish-based food products. First, the amino acid composition in fish protein plays an important role because fish contains more complete and balanced essential amino acids than vegetable protein.[29, 30] Second, various processing methods like heating, drying, and fermentation can either enhance or diminish the digestibility of protein. Heating at the right temperature can increase the availability of amino acids by breaking down the complex structure of proteins. At the same time, excessive heating can form anti-nutritional compounds, such as Maillard bonds, which reduce the availability of lysine.[31]

In addition, the protein's interactions with other components in the formulation affect it. The presence of dietary fiber or anti-nutritional compounds, such as tannins and phytates, can inhibit the action of digestive enzymes, preventing the breakdown of proteins into peptides and amino acids that are more easily absorbed. Conversely, adding proteolytic enzymes or fermenting with certain microbes can increase digestibility by breaking down proteins into simpler forms before consumption.[32] Other factors include the pH of the digestive system and the activity of protease enzymes in the child's body.[33] Children with malnutrition or stunting often experience digestive disorders that can reduce the effectiveness of proteolytic enzymes in breaking down proteins into amino acids.

The highest insoluble dietary fiber was found in F1, followed by F2 and F3. The highest soluble dietary fiber was found in F1, while F2 had the lowest content. The total dietary fiber content showed that F3 had the highest content, followed by F2 and F1. Soluble dietary fiber is a type of fiber that can dissolve in water and form a gel in the digestive tract.[34] In fish-based food products, soluble fiber can come from additional plant materials such as cereal flour, resistant starch, or additives such as gum and pectin. Soluble fiber helps slow digestion, control

blood sugar levels, and lower cholesterol by binding bile acids and fats in the intestines [35].

Insoluble dietary fiber is a type of fiber that does not dissolve in water and remains in its original form when passing through the digestive tract. In fish-based products, insoluble fiber can come from the addition of high-fiber flour, as well as the possibility of structural components of fish, such as skin or connective tissue, that contribute to this fiber content [36, 37]. F1 has the highest insoluble dietary fiber content, indicating the possibility of using additives with the right combination of ingredients.

The study's results show that F1 has the highest soluble dietary fiber content. Total dietary fiber is the sum of soluble and insoluble dietary fiber in a product. The total fiber content of food is very important for overall digestive health because the combination of soluble and insoluble fiber helps improve the balance of the gut microbiota, regulates metabolism, and provides a longer-lasting satiety effect. Formulation F3 has the highest total fiber content of around 14.98, indicating that the combination of ingredients used in F3 makes the largest contribution to overall dietary fiber intake. Fish-based products generally have a naturally low fiber content, so the addition of ingredients such as sago flour can increase the dietary fiber level in the final formulation.

Factors that influence the fiber content of a food product are processing methods. Heating, milling, and extraction can alter the fiber structure, either by increasing its solubility through hydrolysis or by decreasing its content through thermal degradation [38]. Roasting at high temperatures can cause the decomposition of certain fibers, while fermentation with microbes can increase the level of soluble fiber through enzymatic activity. In addition, the interaction between fish protein and other food components, such as polysaccharides from flour or food additives, affects the distribution of soluble and insoluble fiber in the product.

Fiber content is also affected by the type of fish. Fish with high connective tissue can contribute a small amount of insoluble fiber from collagen and elastin [39]. However, if ground fish bones are added in the processing, the insoluble fiber content increases due to the presence of mineral components and structural fibers in the bones.

Dietary fiber, especially soluble fiber, can absorb water and form a gel in the digestive tract. This process slows gastric emptying, so children feel full longer. Stunting children on satiety-inducing foods can help them regulate their diet more regularly, avoid less nutritious foods, and support adequate nutritional intake from the foods they consume.

Insoluble fiber also contributes to the satiety effect by increasing the volume of food in the digestive tract, increasing gastric distension, and sending satiety signals to the brain [40]. This effect is particularly important for stunted children, who

often have a low appetite due to an imbalance in the hunger (ghrelin) and satiety (leptin) hormones.

The highest antioxidant content was found in F1, while F2 had the lowest antioxidant content. Fish meal, used in greater amounts in F1, is a natural source of bioactive compounds with significant antioxidant activity. Fish contains various antioxidant compounds, such as omega-3 fatty acids (EPA and DHA), selenium, and bioactive peptides formed during protein hydrolysis [41]. These compounds help counteract free radicals, reduce oxidative stress, and protect body cells from damage. Several studies have also shown that fish protein can produce bioactive peptides with strong antioxidant properties after undergoing enzymatic processes in the body [42].

Formulation F2, containing more wheat flour, has a lower antioxidant content. Wheat flour is not particularly rich in natural antioxidant compounds because most of its nutritional content consists of complex carbohydrates and gluten. During the processing of wheat flour, some bioactive compounds that may be found in whole wheat grains can also be degraded so that the antioxidant content is further reduced. Wheat flour is more susceptible to fat oxidation during storage and processing than fishmeal, which may contribute to the low antioxidant activity in F2.

The highest calcium (Ca) was found in F1, while F3 had a higher content compared to F2. Fish meal is an excellent source of calcium, mainly if processed from whole fish that include bones and other hard parts. Fish bones contain calcium in the form of calcium phosphate and calcium carbonate, which have high bioavailability and are easily absorbed by the body [43]. Therefore, the F1 formulation, which uses a higher amount of fish meal, has the highest calcium content among the formulations.

Formulation F3 has a higher calcium content than F2, which can be attributed to the difference in the composition of the additional ingredients. F3 uses mineral-rich ingredients, such as sea-based flour or other natural calcium sources, to increase the formulation's calcium content. F2, which contains more wheat flour, has a lower calcium content. Wheat flour is not inherently rich in calcium, as most of the mineral content in wheat is in the outer layers that are often lost during the milling process into fine flour.

Calcium is an essential mineral that is very important for bone and teeth growth, especially for children who experience stunting [44]. Adequate calcium intake helps maintain bone density, supporting optimal growth. In addition, calcium also plays a role in muscle function, nerve transmission, and various metabolic processes in the body [45].

The results showed that the highest iron (Fe) content was found in the F1 formulation, followed by F3 and F2. The difference in iron content is closely related to the composition of the ingredients used, especially the higher proportion of Nile tilapia fish meal in the F1 formulation compared to other

formulations. Nile Tilapia is known to have a significant iron content, especially in protein-rich tissues such as muscles and bones. Therefore, increasing the proportion of Nile tilapia fish meal in the F1 formulation directly contributed to the increase in iron levels detected in the sample. The iron content factor is influenced by factors such as material processing, extraction methods, and manufacturing processes that affect the formulation's bioavailability of iron. For example, improper heating or the use of iron absorption inhibitors (such as some types of fiber or phytic acid) can reduce the efficiency of iron absorption in the human body, even though the iron content in the starting material is high.

The highest energy content was found in F1, followed by F2, and F3 had the lowest. Formulation F1 had the highest energy content, which was most likely due to the higher proportion of ingredients rich in fat and protein. If F1 contained more fishmeal, this could increase the fat and protein content because fish is a source of healthy fats, such as omega-3 fatty acids, as well as proteins with high biological value [22]. Fat has the highest energy density among other macronutrients, so the higher fat content in F1 contributes to a higher total energy than other formulations.

Formulation F2 has a lower energy content than F1 but higher than F3. If F2 contains more wheat flour than F3, its carbohydrate content is higher, which is the main source of energy. However, if the fat content in F2 is lower than in F1, then the total energy produced is also lower. Carbohydrates are easier to digest and convert into energy than fat, so F2 still has a fairly high energy content even though it is lower than F1.

Formulation F3 has the lowest energy content, which can be attributed to its composition, with more fiber-rich ingredients or lower-fat ingredients. If F3 has a higher proportion of sago flour, then its energy source comes more from simple carbohydrates, which have a lower energy density than fat. In addition, dietary fiber in sago flour or other ingredients can reduce the total energy density because it is indigestible and does not provide significant energy.

One of the main challenges in providing additional food for stunted children is consumption preferences. According to the Directorate of Community Nutrition of the Ministry of Health (2020), children tend to prefer snacks that are generally low in nutrients compared to nutrient-dense foods such as fish and vegetables. Therefore, the development of food innovations such as high-protein dry noodles, Sagurimi, is a potential solution.

Based on the results of this study and previous studies, the formulation of Sagurimi with the best composition can serve as an additional food for stunted children. The use of local foods rich in protein, iron, and calcium in this product supports national efforts to reduce stunting rates, in line with Presidential Regulation No. 42 of 2013 concerning the National Movement to Accelerate Nutrition Improvement.

Thus, this innovation not only improves children's nutritional status but also encourages the optimal use of local food resources. According to the 2019 Indonesian Recommended Dietary Allowance (AKG), children aged 3–5 years require approximately 20–25 grams of protein per day. Sagurimi shows strong market potential, as its protein content (8 g per serving) is considerably higher than that of most commercial products, which typically contain only around 1 g of protein. This highlights Sagurimi's competitive advantage as a high-protein functional food for children.

IV. CONCLUSION

According to the study's findings, F1 is a good option for meeting the nutritional needs of stunted infants because it has the highest nutrient content, including protein, fat, calcium, and antioxidants. The usage of tilapia fish meal, which is abundant in vital nutrients, including omega-3 fatty acids, premium protein, and minerals critical for children's growth and development, is the reason behind Formula One's success. In contrast, the F2 formulation, which has less protein than the F1 formulation but more wheat flour, provides energy more quickly. F2 is a good choice for youngsters who are busy and full of energy because its components are designed to provide a source of energy they can use right away to support their everyday activities and development. Protein and antioxidant content, whereas F3's utilization of sago flour provides the advantages of higher fiber and improved iron content. The study's sustainability implications are that food innovations based on local ingredients, such as fish meal, can effectively combat stunting by supporting national nutrition programs and promoting the best possible use of local food resources. This study will be continued to evaluate the effect of Sagurimi consumption on IGF-1 and osteocalcin levels in stunted children aged 3–5 years. The product also has potential for application in community nutrition and school feeding programs to support efforts in reducing stunting prevalence.

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CONFLICT OF INTEREST

The authors declare no conflict of interest to disclose.

REFERENCES

- [1] K. K. R. Indonesia, "Results of the Indonesian Nutritional Status Study (SSGI) at the National, Provincial, and Regency/City Levels in 2021," *Kementrian Kesehatan RI*, 2021. p. 6–133.
- [2] L. L. Manalor *et al.*, M. B. Bakoil, Ed. *Pemberdayaan Masyarakat dalam Upaya Pencegaha Stunting*, 1 ed. Malang: Penerbit Rena Cipta Mandiri, 2023.
- [3] R. R. Akbar, W. Kartika, and M. Khairunnisa, "The Effect of Stunting on Child Growth and Development," *Scientific Journal*, vol. 2, no. 4, 2023, doi: <https://doi.org/10.56260/sciENA.v2i4.118>.
- [4] N. N. Wirawan, U. Fahmida, R. C. Purwestri, I. S. Timan, B. Hegar, and B. Hegar, "Development of Food Multi-Mix Using a Linear Programming Approach to Fill the Nutrient Gap of Amino Acids and Micronutrients for Stunted Non-Wasted Children," *Foods*, vol. 12, no. 1, p. 64, 2022, doi: <https://doi.org/10.3390/foods12010064>.
- [5] E. K. Arnesen *et al.*, "Protein intake in children and growth and risk of overweight or obesity: A systematic review and meta-analysis," *Food & nutrition research*, 2022, doi: 10.29219/fnr.v66.8242.
- [6] S. Suparmi, S. Sumarto, U. Afriana, and T. Hidayat, "Utilization of Biang Fish Flour (*Ilisha elongata*) as an Enrichment Material for Sago Noodles Nutrient Value," *International Journal of Biomaterials*, 2022, doi: <https://doi.org/10.1155/2022/8746296>.
- [7] Raatz, S., Bibus, D., 2016. "Fish and Fish Oil in Health and Disease Prevention," Academic Press.
- [8] H. M. M. El-Khayat, S. S. M. Sayed, W. A. Mohammed, and A.-S. M. Sade, "Protozoan and helminths infestation of Nile tilapia *Oreochromis niloticus* and its correlation with certain water quality variables along river Nile in the area of Greater Cairo," *Environmental Pollution*, vol. 345, 2024, doi: <https://doi.org/10.1016/j.envpol.2024.123459>.
- [9] R. Olson *et al.*, "Perceptions of In-Home Usage Experience and Price: Results of Consumer Research on Nutritional Innovations for Improving Maternal and Child Nutrition in Ethiopia," *Food Science and Nutrition*, vol. 13, 2025, doi: <https://doi.org/10.1002/fsn3.4758>.
- [10] N. Resti *et al.*, "Physicochemical quality of dry noodles from maize four and fish protein hydrolyzate (Mizepi) as a potential emergency food," *Food Production, Processing and Nutrition*, vol. 6, no. 92, 2024, doi: <https://doi.org/10.1186/s43014-024-00266-0>.
- [11] Y. Akhsanitaqwm, N. I. D. Arista, and A. Septiyanto, "Biofortified biscuits with indigenous plants: An innovative approach to prevent stunting in early childhood," *Public Health Risk Assessment Journal*, vol. 2, no. 1, 2024, doi: <https://doi.org/10.61511/phraj.v2i1.2024.814>.
- [12] B. Pardamean *et al.*, "Monitoring and evaluation of childhood stunting reduction program based on fish supplement product in North Sumatera, Indonesia," *Scientific reports*, vol. 22, no. 14, 2024, doi: 10.1038/s41598-024-61462-z.
- [13] AOAC, *Official method of analysis of the association of official analytical of chemist*. Arlington, TX: The Association of Official Analytical Chemist, 2005.
- [14] S. S. Nielsen, *Food Analysis*. New York, 2008.
- [15] L. Niu and D. Han, *Chemical Analysis of Antioxidant Capacity*. 2020.
- [16] H. Liua, Y. Zhang, X. Pei, Z. Xie, K. Shi, and A. Li, "Effects of standard wheat flour proportion in total dietary carbohydrates on blood glucose, lipid metabolism, and inflammation in mice," *Food and Agricultural Immunology*, vol. 30, no. 1, 2019, doi: <https://doi.org/10.1080/09540105.2019.1635088>.
- [17] N. Vartolomei and M. Turtoi, "The Influence of the Addition of Rosehip Powder to Wheat Flour on the Dough Farinographic Properties and Bread Physico-Chemical Characteristics," *Applied Sciences*, vol. 11, no. 24, p. 12035, 2021, doi: <https://doi.org/10.3390/app112412035>.
- [18] A. T. Y. Kishawy *et al.*, "Partial defatted black soldier larvae meal as a promising strategy to replace fish meal protein in diet for Nile tilapia (*Oreochromis niloticus*): Performance, expression of protein and fat transporters, and cytokines related genes and economic efficiency," *Aquaculture*, vol. 555, 2022, doi: <https://doi.org/10.1016/j.aquaculture.2022.738195>.
- [19] S. S. Corrêa *et al.*, "Quality of *Oreochromis niloticus* and *Cynoscion virescens* fillets and their by-products in flours make for inclusion in instant food products," *Plus One*, 2023, doi: <https://doi.org/10.1371/journal.pone.0279351>.
- [20] S. Maulu, K. Nawanzi, M. Abdel-Tawwab, and H. S. Khalil, "Fish Nutritional Value as an Approach to Children's Nutrition," *Frontiers*, vol. 8, 2021, doi: <https://doi.org/10.3389/fnut.2021.780844>.
- [21] S. Phogat, T. Dahiya, M. Jangra, A. Kumari, and A. Kumar, "Nutritional Benefits of Fish Consumption for Humans: A Review," *International Journal of*

- Environment and Climate Change*, vol. 12, no. 12, pp. 1443-1457, 2022, doi: <https://www.sdiarticle5.com/review-history/96161>.
- [22] S. K. Tilami and S. Sampels, "Nutritional Value of Fish: Lipids, Proteins, Vitamins, and Minerals," *Review in Fishers Science&Aquaculture*, vol. 26, no. 2, 2017, doi: <https://doi.org/10.1080/23308249.2017.1399104>.
- [23] Y. Cheng *et al.*, "Evaluate of Wheat Gluten as a Protein Alternative for Fish Meal and Soy Protein Concentrate in Red Spotted Grouper *Epinephelus akaara*," *Metabolites*, vol. 13, no. 7, p. 832, 2023, doi: <https://doi.org/10.3390/metabo13070832>.
- [24] C. J. Simon, H. Truong, N. Habilay, and B. Hines, "Feeding Behaviour and Bioavailability of Essential Amino Acids in Shrimp *Penaeus monodon* Fed Fresh and Leached Fishmeal and Fishmeal-Free Diets," *Animals*, vol. 11, no. 3, p. 847, 2021, doi: <https://doi.org/10.3390/ani11030847>.
- [25] B. Pardamean *et al.*, "Monitoring and evaluation of childhood stunting reduction program based on fish supplement product in North Sumatera, Indonesia," *scientific reports*, vol. 14, no. 11674, 2024, doi: <https://doi.org/10.1038/s41598-024-61462-z>.
- [26] G. N. Yanti, I. Yustina, A. Primasari, and R. K. Rochadi, "Effectiveness of Rebon Shrimp in Preventing Dental Caries among Elementary School Children in Bagan Serdang Village," *Journal of International Dental and Medical Research*, vol. 15, no. 4, p. 1718, 2022.
- [27] F. A. Taiwo-Olabode, M. T. Ukeyima, and V. N. Enujiugha, "In vitro Protein and Starch Digestibility, Nutritional and Bioactive Properties of Elekute (A Maize-Based Snack) Substituted with Catfish (*Clarias gariepinus*)," *IPS Journal of Nutrition and Food Science*, vol. 3, no. 3, 2024, doi: <https://doi.org/10.54117/ijnfs.v3i3.59>.
- [28] Najam-Us-Sahar *et al.*, *Replacement of vegetable protein sources with marine by-product on nutrient utilization, protein digestibility, meat quality and economics in Ross-308 broilers*. Pakistan: Friends Science Publishers, 2022.
- [29] C. George and C. N. Ravishankar, "Effect of Extrusion Processing Parameters on Physical and Nutritional Properties of Fish Based Snack- A Review," *Fishery Technology*, vol. 59, pp. 225-237, 2022.
- [30] S. Rathlavath, V. K. R. Surasani, V. S. R. Govinda, J. B. Siddhnath, A. Singh, and A. S. Desai, "Fish protein-supplemented pasta and its technological aspects," *International Journal of Food Science and Technology*, vol. 59, no. 11, 2024, doi: <https://doi.org/10.1111/ijfs.17564>.
- [31] A. Badjona, R. Bradshaw, C. Millman, M. Howarth, and B. Dubey, "Faba Bean Processing: Thermal and Non-Thermal Processing on Chemical, Antinutritional Factors, and Pharmacological Properties," *molecules*, vol. 28, no. 14, p. 5431, 2023, doi: <https://doi.org/10.3390/molecules28145431>.
- [32] Y. Cao, M. Xu, J. Lu, and G. Cai, "Simultaneous Microbial Fermentation and Enzymolysis: A Biotechnology Strategy to Improve the Nutritional and Functional Quality of Soybean Meal," *Food Review International*, vol. 40, no. 5, 2023, doi: <https://doi.org/10.1080/87559129.2023.2212048>.
- [33] L. P. Guamán, S. E. Carrera-Pacheco, J. Zúñiga-Miranda, E. Teran, C. Erazo, and C. Barba-Ostria, "The Impact of Bioactive Molecules from Probiotics on Child Health: A Comprehensive Review," *nutrients*, vol. 16, no. 21, p. 3706, 2024, doi: <https://doi.org/10.3390/nu16213706>.
- [34] S. K. Gill, M. Rossi, B. Bajka, and K. Whelan, "Dietary fiber in gastrointestinal health and disease," *Nature Reviews Gastroenterology & Hepatology*, vol. 18, pp. 101-116, 2020.
- [35] W. Khalid, M. S. Arshad, A. Jabeen, F. M. Anjum, T. B. Qaisrani, and H. A. R. Suleria, "Fiber-enriched botanicals: A therapeutic tool against certain metabolic ailment," *Food Science and Nutrition*, 2022, doi: <https://doi.org/10.1002/fsn3.2920>.
- [36] F. Subhan, Z. Hussain, I. Tauseef, A. Shehzad, and F. Wahid, "A review on recent advances and applications of fish collagen," *Critical Reviews in Food Science and Nutrition*, vol. 61, no. 6, 2021, doi: <https://doi.org/10.1080/10408398.2020.1751585>.
- [37] H. Ahn *et al.*, "Mechanical Properties of Porcine and Fish Skin-Based Collagen and Conjugated Collagen Fibers," *polymers*, vol. 13, no. 13, p. 2151, 2021, doi: <https://doi.org/10.3390/polym13132151>.
- [38] J. Gan, L. Xie, G. Peng, J. Xie, Y. Chen, and Q. Yu, "Systematic review on modification methods of dietary fiber," *Food Hydrocolloids*, vol. 119, 2021, doi: <https://doi.org/10.1016/j.foodhyd.2021.106872>.
- [39] A. M. Holwerda and L. J. C. v. Loon, "The impact of collagen protein ingestion on musculoskeletal connective tissue remodeling: a narrative review," *Nutrition Reviews*, vol. 80, no. 6, pp. 1497-1514, 2022, doi: <https://doi.org/10.1093/nutrit/nuab083>.

- [40] M. Akhlaghi, "The role of dietary fibers in regulating appetite, an overview of mechanisms and weight consequences," *Critical Reviews in Food Science and Nutrition* vol. 64, no. 10, doi: <https://doi.org/10.1080/10408398.2022.2130160>.
- [41] C. G. Awuchi *et al.*, "Bioactive Compounds and Therapeutics from Fish: Revisiting Their Suitability in Functional Foods to Enhance Human Wellbeing," *BioMed Research International*, 2022, doi: <https://doi.org/10.1155/2022/3661866>.
- [42] N. P. Nirmal, C. Santivarangkna, M. S. Rajput, S. Benjakul, and S. Maqsood, "Valorization of fish byproducts: Sources to end-product applications of bioactive protein hydrolysate," *Comprehensive Reviews in Food Science and Food Safety*, 2022, doi: <https://doi.org/10.1111/1541-4337.12917>.
- [43] B. Torres *et al.*, "Fish Bones as Calcium Source: Bioavailability of Micro and Nano Particles," *foods*, vol. 13, no. 12, 2024, doi: <https://doi.org/10.3390/foods13121840>.
- [44] U. Tedjosongko, A. L. Salsabilla, and I. Salim, "The correlation between oral health and stunting in children: A literature review," *World Journal of Advanced Research and Reviews*, vol. 21, no. 01, pp. 489-493, 2024, doi: <https://doi.org/10.30574/wjarr.2024.21.1.2732>.
- [45] N. Wawrzyniak and J. Suliburska, "Nutritional and health factors affecting the bioavailability of calcium: a narrative review," *Nutrition Reviews*, vol. 79, no. 12, pp. 1307-1320, 2021, doi: <https://doi.org/10.1093/nutrit/nuaa138>.