E-ISSN: 2614-0934
SEAS (Sustainable Environment Agricultural Science)
https://www.ejournal.warmadewa.ac.id/index.php/seas
https://doi.org/10.22225/seas.10.1.14408.20-30

Dried Noodles Enriched with Black Soldier Fly Larvae Flour as a Novel Strategy for Stunting Prevention

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Article info :
Article History:
Received: January 29, 2026
Revision: April 5, 2026
Accepted: April 27, 2026
Online Publication: April 30, 2026

Abstract
Stunting remains a major public health problem in Indonesia and is closely associated with chronic protein deficiency in children. The development of affordable, nutrient-dense food products is therefore essential to support stunting prevention programs. This study aimed to develop protein-enriched dried noodles using Black Soldier Fly Larvae (BSFL) flour as an alternative functional food ingredient and to evaluate their sensory and proximate characteristics. Dried noodles were formulated with three different substitution ratios of BSFL flour to wheat flour, namely 50:50, 60:40, and 40:60. Sensory evaluation was conducted using a hedonic test involving 20 semi-trained panelists to assess color, aroma, texture, taste, and overall acceptability. The formulation with the highest sensory acceptance was further subjected to proximate analysis, including protein, moisture, and ash content. The results indicated that the formulation 50:50 achieved the highest overall acceptability score and was categorized as "liked" by panelists. Proximate analysis of the selected formulation showed a protein content of 23.3%, moisture content of 12.9%, and ash content of 5.3%. The moisture content met the Indonesian National Standard (SNI 8217:2015) requirement for dried noodles, indicating good product stability. The incorporation of BSFL flour significantly increased the protein content of dried noodles compared to conventional wheat-based products while maintaining acceptable sensory quality. In addition, the use of insect-based protein supports sustainable food production by utilizing environmentally friendly resources. Overall, BSFL-enriched dried noodles demonstrate strong potential as a high-protein functional food product that can contribute to improving dietary protein intake and supporting stunting reduction efforts in Indonesia.

Keywords:
Black soldier fly larvae, dried noodles, sensory evaluation, flour, characterisctics

1. Introduction

Stunting is a condition associated with chronic malnutrition, particularly affecting children. Inadequate nutrient intake can lead to impaired growth, reduced muscle mass, and weight loss. The World Health Organization (WHO) defines stunting as a condition in children under five years of age characterized by a height-for-age ratio below the standard growth reference. Although the prevalence of stunting in Indonesia has declined to 27.67%, this figure still exceeds the WHO threshold, which recommends that stunting prevalence should be below 20% [1]. Stunting remains a serious public health challenge in Indonesia, prompting the government to implement the National Strategy for Accelerating Stunting Reduction. This program involves multisectoral collaboration among government institutions, private sectors, academia, communities, philanthropic organizations, and mass media. Such cross-sector cooperation is essential to ensure the effectiveness of intervention strategies. In 2024, the Indonesian government targeted a reduction in stunting prevalence to 14%, a more ambitious goal compared to the 19% target established by the Ministry of National Development Planning (Bappenas) [2].

Genetic factors contribute approximately 15% to the risk of stunting, while the primary determinants include inadequate nutritional intake, growth hormone disorders, and recurrent infections [2]. Protein is one of the most critical nutrients required to support optimal child growth and prevent stunting. Increasing the consumption of protein-rich foods represents an effective strategy to address protein-energy malnutrition. One underutilized yet highly promising protein source is Black Soldier Fly Larvae (BSFL) flour. BSFL is an insect-based ingredient with a remarkably high protein content. Based on several researches, BSFL flour contains 57.86% protein [3], which is considerably higher than soybean flour (41.64%) [4], mung bean flour (22.75%) [5], red bean flour (19.08%) [6], black pigeon pea flou (24.32%) [7], sword bean flour (29.18%) [8], and tofu by-product flour (21.53%) [9]. Furthermore, BSFL flour contains 15 amino acids, comprising eight essential and seven non-essential amino acids [10]. In addition to protein, BSFL is rich in minerals such as potassium, sodium, calcium, copper, iron, zinc, manganese, and phosphorus [11]. BSFL contains moisture levels ranging from 2.08% to 2.46%, ash content of 7.59%–10.2%, lipid content of 32.2%–40.08%, and crude fiber content of 7.9%–15.87% [12].

The cultivation of insects such as BSFL also contributes to environmental sustainability by reducing food waste, which refers to edible food discarded either before or after expiration [13]. According to the United Nations Environment Programme (UNEP) report in 2021, Indonesia generates approximately 19 million tons of food waste annually, posing significant environmental challenges if not properly managed [14]. BSFL farming offers a practical solution by utilizing vegetable and fruit waste that remains safe for consumption but is no longer marketable as feed substrates. This cultivation process is conducted under hygienic conditions to prevent contamination and ensure the production of high-quality BSFL flour. BSFL flour has been widely explored for both food and non-food applications, including its use in tortilla chips [3], cookies [15], biscuits [16], snack bars [17].

One commonly consumed food product that can be fortified using BSFL flour is dried noodles. Dried noodles are raw noodles processed through dehydration to achieve a moisture content of approximately 8–10% [18]. Due to their extended shelf life and ease of preparation, dried noodles are highly favored across various population groups. Data from the 2023 National Socio-Economic Survey (SUSENAS) indicated that approximately 92% of Indonesians, or about 248.7 million people, consume instant noodles [19]. Conventional dried noodles are primarily made from wheat flour and typically contain only 9.67% protein. Therefore, incorporating BSFL flour into dried noodle formulations represents a promising approach to developing protein-enriched products aimed at supporting stunting reduction efforts.

2. Material and Methods

2.1 Loacation and time of research

This research was conducted at the Food Processing Laboratory and Food Analysis Laboratory, Faculty of Agricultural Technology, Udayana University. The research activities, including experimental procedures and data analysis, were carried out from September to December 2025.

2.2 Material and equiptment

This research utilized several materials, including maggots (Black Soldier Fly Larvae), wheat flour, salt, baking soda, eggs, Kjeldahl tablets, sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), boric acid, and hydrochloric acid (HCl). The equipment employed in this research comprised an analytical balance, mixing bowls, stove, plates, oven, pots, roasting equipment, draining tools, grinder, sieve, noodle molding machine, colorimeter, texture analyzer, moisture content dishes, porcelain crucibles, muffle furnace, distillation unit, and standard laboratory glassware.

2.3 Research Procedure

Preparation of Maggot Black Soldier Fly Larvae Flour

Black Soldier Fly larvae (BSFL) were used as the primary raw material for flour production. The larvae were initially sun-dried for two days and then ground into a coarse form. The ground material was subsequently subjected to a defatting process to reduce lipid content and improve the shelf stability of the flour. After defatting, the material was further dried in a hot-air oven at 50°C for 7 hours, followed by roasting at 100°C for 15 minutes to minimize residual moisture and enhance product stability. The roasted material was then drained and sun-dried again until completely dry. Finally, the dried product was milled and sieved through a 60-mesh sieve to obtain fine BSFL flour.

Preparation of Maggot Black Soldier Fly Larvae Noodles

Wheat flour and BSFL flour were mixed according to the formulation ratios specified in Table 1. Additional ingredients, including eggs (60 g), baking soda (0.6 g), salt (2.6 g), and water as needed, were added and mixed until a homogeneous dough was obtained. The dough was then processed using a noodle-making machine to form noodle sheets. The formed noodles were steamed for 10 minutes and subsequently dried in an oven at 60°C for 3 hours. The resulting Maggot Black Soldier Larvae instant noodle product was subjected to sensory evaluation, including color, aroma, texture, taste, and overall acceptability. The formulation with the highest sensory acceptance was further analyzed for proximate composition, including protein content, moisture content, and ash content.

Table 1.
Maggot Noodle Formulation Treatments

Treatments	Formulation (g)				
	Wheat Flour	Maggot Flour	Egg	Baking Soda	Salt
M1	60	40	60	0.6	2.6
M2	50	50	60	0.6	2.6
M3	40	60	60	0.6	2.6

2.4 Analytical Techniques

1. **Sensory Evaluation**

Sensory analysis was conducted using 20 semi-trained panelists aged between 20 and 30 years who regularly consume noodle products. A hedonic test was performed to evaluate several sensory attributes, including color, aroma, texture, taste, and overall acceptability. The hedonic scale ranged from 1 to 5, where 5 = like very much, 4 = like moderately, 3 = neutral, 2 = dislike moderately, and 1 = dislike very much [20].

2. **Moisture Content Analysis**

Moisture content was determined using the oven-drying method. Aluminum moisture dishes were preheated in an oven at 105 °C for 1 h, cooled in a desiccator for 15 min, and weighed. Approximately 2 g of noodle sample was placed into the dish and dried at 105 °C for 4 h. The dish containing the sample was then cooled in a desiccator and weighed. The drying process was repeated for an additional 1 h, followed by cooling and reweighing until a constant weight was obtained. Moisture content of maggot noodles was calculated based on the difference between initial and final weights according to the AOAC method [21].

$$\text{Moisture content (\%)} = \frac{\text{initial weight (g)} - \text{final weight (g)}}{\text{initial weight (g)}} \, 100\%$$

3. **Ash Content Analysis**

Ash content was determined following the AOAC method [21]. Porcelain crucibles were preheated in an oven at 105 °C for 1 h, cooled in a desiccator for 15 min, and weighed. Approximately 2 g of noodle sample was placed into the crucible and pre-incinerated on an electric stove until smoke emission ceased. The crucible containing the sample was then transferred to a muffle furnace and ashed at 600 °C for 6 h until white ash was obtained. After ashing, the crucible was cooled in a desiccator for 15 min and weighed.

$$\text{Ash content (\%)} = \frac{\text{ash weight (g)}}{\text{sample weight (g)}} \, 100\%$$

4. **Protein Content Analysis**

Protein content was determined using the Kjeldahl method [22]. Approximately 0.1 g of noodle sample was digested with concentrated sulfuric acid (H_2SO_4) and a Kjeldahl catalyst tablet under heating until a clear solution was obtained. After cooling, 25 mL of distilled water was added, and the digest was transferred to a Kjeldahl flask. Subsequently, 50% sodium hydroxide (NaOH) solution and three drops of phenolphthalein indicator were added. The liberated ammonia was distilled into 10 mL of 3% boric acid solution and titrated with 0.1 N hydrochloric acid (HCl) until the color changed from blue to yellow.

$$\text{N \%} = \frac{((\text{a} - \text{b})\text{x } 0.1 \text{ x } 14.007)}{\text{c}} \, 100\%$$

$$\%\, Protein = \%\text{N x } 6.25$$

Description:

a= volume of sam0ple titration (mL)

b= volume of blanko titration (mL)

c= sample (mg)

2.5 Data Analysis

The experiment was designed using a Completely Randomized Design (CRD) with one factor consisting of three treatment levels: M1 (60:40), M2 (50:50), and M3 (40:60), representing the ratio of maggot flour to wheat flour. Each treatment was replicated six times. The analyses included hedonic sensory evaluation and proximate composition testing, conducted in accordance with SNI

8217:2015 standards. Statistical analysis was performed using Minitab version 19 software. When significant treatment effects were observed, mean comparisons were conducted using Tukey's Honestly Significant Difference (HSD) test at a 95% confidence level ($p < 0.05$).

3. Results and Discussion

The sensory evaluation results indicated that the formulation ratio of maggot flour and wheat flour had a significant effect on the sensory characteristics of maggot noodles. The sensory attributes evaluated, including color, aroma, texture, taste, and overall acceptability, are presented in Table 3. In addition to sensory assessment, the physical characteristics of maggot noodles were instrumentally analyzed, including color measurements using a colorimeter and texture measurements using a texture analyzer. The corresponding results are also summarized in Table 3.

3.1 Sensory evaluation of Maggot Black Soldier Fly Larvae Noodles

The results can be presented in figures, graphs, tables and others. The section discusses the results of data processing, interprets the findings logically, relates them to the relevant referral source.

Table 2.
Sensory Evaluation Results of Maggot Black Soldier Fly Larvae Noodles

Sample	Colour	Aroma	Texture	Taste	Overall Aceptence
M1 (60:40)	3.58 ± 0.88 b	2.74 ± 0,96 b	3.11 ± 0.85b	3.00 ± 0.92 b	3.26 ± 0.64 b
M2 (50:50)	4.74 ± 0.55 a	3.68 ± 1,17 a	3.79 ± 0.95 a	3.79 ± 0.61 a	4.32 ± 0.57 a
M3 (40:60)	2.63 ± 0.87 c	2.47 ± 0,99 b	2.68 ± 0.98 b	2.37 ± 0.87 c	2.53 ± 0.75 b

Notes: The numbers in the sample ratio represent the ratio of wheat flour to maggot flour. Values in the same column followed by identical superscript letters indicate no significant difference ($P > 0.05$). Hedonic scale criteria were defined as follows: 5 = strongly like, 4 = moderately like, 3 = neutral, 2 = moderately dislike, and 1 = strongly dislike.

Table 3.
Results of Color and Texture Analysis of Maggot Black Soldier Fly Larvae Noodles

Sample	Colour Testing			Texture Analyzer (Newtons)
	L*	a*	b*	
M1 (60:40)	22.9 ± 1,30	16.2 ± 0,39	11.5 ± 1,45	51.53 ± 2,23
M2 (50:50)	30.0 ± 1,73	15.0 ± 0,69	18.9 ± 1,70	40.74 ± 3,26
M3 (40:60)	22.6 ± 1,92	15.7 ± 0,43	11.6 ± 1,66	24.00 ± 1,41

Notes: The numbers in the sample ratio represent the ratio of wheat flour to maggot flour.

Colour

The sensory evaluation of color attributes indicated that the 50:50 formulation of maggot flour and wheat flour achieved the highest preference score and was categorized within the "liked" criterion. This finding suggests that increasing the proportion of BSFL flour tends to reduce panelist acceptance, particularly in terms of visual appearance. The decrease in preference is primarily attributed to the inherent brownish color of BSFL flour, which intensifies the dark appearance of maggot noodles and makes them less visually appealing to consumers [16]. Color is a critical quality parameter that strongly influences consumer perception and initial product acceptance, as visual appearance often determines purchase intention prior to sensory evaluation of other attributes.

Instrumental color analysis using a colorimeter further supported the sensory results. The 50:50 formulation exhibited average L*, a*, and b* values of 30, 15, and 18.9, respectively. The relatively low L* value indicates reduced brightness, while positive a* and b* values reflect reddish and yellowish tones, which are associated with the presence of insect-derived pigments and thermal processing effects. The darker color formation may also be influenced by Maillard reactions occurring during drying and roasting processes, which contribute to browning and color development in protein-rich ingredients.

Furthermore, BSFL naturally exhibits a pale yellow to cream coloration; however, lipid oxidation and enzymatic browning during processing can promote pigment degradation and darkening, resulting in a darker flour appearance [23]. Consequently, higher substitution levels of BSFL flour intensify the color of the final noodle product. These findings highlight the importance of optimizing substitution ratios to balance nutritional enhancement and consumer acceptance. Maintaining a moderate inclusion level, such as the 50:50 formulation, appears to be an effective strategy to improve protein content while preserving desirable visual quality.

Aroma

The sensory evaluation of aroma indicated that the 50:50 formulation achieved the highest acceptance level and was categorized as "moderately liked." This result suggests that a balanced proportion of BSFL flour and wheat flour is able to maintain an aroma profile that remains acceptable to panelists without producing excessively strong off-odors. The decrease in aroma preference observed at higher substitution levels of BSFL flour is likely associated with the characteristic rancid odor of BSFL flour. Swamilaksita et al. reported that this odor is mainly caused by the high lipid content of BSFL flour, which is highly susceptible to oxidative reactions during processing and storage [16]. In addition, thermal treatments such as drying and roasting may further accelerate lipid oxidation and degradation, leading to the formation of volatile aldehydes, ketones, and other secondary oxidation products that contribute to undesirable aroma development. Consequently, excessive incorporation of BSFL flour can intensify these off-odors, thereby reducing consumer acceptance of the final noodle product.

Texture

Based on the sensory evaluation results presented in Table 2, the 50:50 formulation demonstrated the highest level of acceptance for texture and fell within the "moderately liked" category, suggesting the most favorable textural characteristics. Increasing the proportion of BSFL flour resulted in a reduction in noodle hardness, leading to a softer, more brittle, and less elastic structure. This phenomenon is closely related to differences in protein composition and functional properties between wheat flour and BSFL flour. Wheat flour contains gluten-forming proteins, primarily gliadin and glutenin, which are responsible for developing a cohesive and elastic dough matrix that contributes to structural integrity and desirable chewiness in noodle products. In contrast, BSFL flour lacks gluten proteins and therefore cannot form a comparable viscoelastic network.

According to Zhafira and Farida, the breaking strength of dried noodles is influenced by protein content, where higher protein levels generally tend to increase breaking strength [18]. However, the present findings suggest that protein functionality plays a more critical role than protein quantity alone. Although BSFL flour contributes to an overall increase in protein content, its non-gluten proteins are unable to provide the same structural reinforcement as wheat gluten. As a result, excessive substitution weakens the noodle matrix and reduces mechanical strength. Therefore, the 50:50 formulation can be considered an optimal ratio, as it maintains sufficient gluten content to preserve structural integrity while simultaneously enhancing nutritional value, resulting in a product with acceptable firmness, elasticity, and overall textural quality.

Taste

In terms of taste, the sensory evaluation results demonstrated that the 50:50 formulation achieved the highest acceptance level and was classified as "moderately liked." This finding indicates that a balanced proportion of BSFL flour and wheat flour can maintain acceptable palatability, whereas higher levels of BSFL flour substitution tend to decrease panelists' preference for maggot noodles. The reduction in taste acceptability is primarily associated with the characteristic bitter aftertaste of BSFL flour, which has been reported to negatively influence consumer perception [16]. This bitter sensation is likely related to the presence of bioactive compounds, peptides, and certain amino acids that may impart a strong flavor profile when used at high concentrations. In addition, thermal processing steps such as drying and roasting can induce Maillard reactions and lipid oxidation, which may generate secondary flavor compounds that further intensify undesirable taste notes. As the proportion of BSFL flour increases, these flavor attributes become more pronounced, thereby reducing overall product palatability. Therefore, the 50:50 formulation can be considered an optimal ratio that balances nutritional enhancement with sensory acceptability, particularly in maintaining a more neutral taste profile that is better accepted by consumers.

Overall acceptence

The sensory evaluation results indicated that the highest overall acceptability of maggot noodles was achieved by the 50:50 formulation of maggot flour and wheat flour, which was classified in the "liked" category. This finding suggests that the selected formulation provided an optimal balance between sensory quality and product performance. Based on the sensory assessment, the 50:50 formulation was identified as the best treatment, as it obtained the highest scores for color, aroma, texture, taste, and overall acceptability compared to the other formulations. This result demonstrates that a moderate substitution level of BSFL flour can maintain desirable organoleptic characteristics without causing excessive sensory deviations.

Overall acceptability is a critical indicator of product feasibility and consumer preference, as it reflects the combined perception of multiple sensory attributes. The high acceptance level observed for the 50:50 formulation indicates its strong potential for consumer acceptance as a protein-enriched noodle product. Therefore, this optimal formulation was subsequently selected for proximate analysis, including protein content, moisture content, and ash content, in order to evaluate its nutritional quality and physicochemical characteristics. These analyses are essential to assess the contribution of BSFL flour to the nutritional value of the product and its compliance with quality standards for dried noodle products.

3.2 Proximate analysis of Maggot Black Soldier Fly Larvae Noodles

Proximate analysis of maggot noodles was conducted on the best treatment from the previous stage, specifically M2 (50:50). The test parameters for maggot noodles included protein content, moisture content, and ash content, which can be seen in Table 4.

Table 4.

Test Parameters for Maggot Noodles

Test Parameters	Levels (%)
Protein content	23.3 ± 0,16
Moisture content	12.9 ± 0,22
Ash content	5.3 ± 0,08

Figure 1.
Maggot Black Soldier Fly Larvae Noodles in a 50:50 ration

Protein content of Maggot Black Soldier Fly Larvae Noodles

Based on proximate analysis, maggot noodles produced using the optimal formulation (50:50) exhibited an average protein content of 23.3%. This value indicates that the developed product contains a relatively high protein level compared to several conventional protein sources, such as tempeh (17.39**%**) [24], tofu (21.11%) [25], and chicken eggs, which typically contain 12–16% protein [26]. These findings demonstrate that the substitution of BSFL flour in dried noodle production significantly enhances the protein content of the final product, highlighting its potential as a high-protein food alternative.

The elevated protein content of maggot noodles is strongly influenced by the composition of raw materials, particularly the incorporation of BSFL flour, which has been reported to contain up to 57.86% protein [3]. The high protein concentration in BSFL flour is associated with its rich and diverse amino acid profile. Agus et al. reported that BSFL flour contains various amino acids, including L-glutamic acid, glycine, L-leucine, L-arginine, L-tyrosine, L-valine, L-aspartic acid, L-proline, L-phenylalanine, L-alanine, L-serine, L-isoleucine, L-threonine, L-lysine, L-cystine, L-histidine, L-tryptophan, and L-methionine [27].

These results are consistent with the findings of Widianingrum et al. who reported that BSFL flour possesses a complete amino acid profile, with the highest concentrations observed for glutamate (7,685.84 mg/kg), aspartate (5,864.19 mg/kg), and leucine (5,034.31 mg/kg) [28] . The presence of essential and non-essential amino acids in substantial amounts is nutritionally important, as these compounds play key roles in protein synthesis, tissue growth, and muscle development. Therefore, maggot noodles formulated with BSFL flour offer strong potential as a functional food product that can contribute to improving dietary protein intake and supporting nutritional intervention programs, particularly those aimed at addressing stunting and malnutrition.

Moisture content of Maggot Black Soldier Fly Larvae Noodles

The test results showed that maggot noodles had a moisture content of 12.9%. This value meets the quality requirements for dried noodles according to SNI 8217:2015, which specifies a maximum allowable moisture content of 13% [29]. Compliance with this standard indicates that the processing and drying stages of maggot noodle production were conducted optimally, resulting in a product with good stability during storage. The moisture content of maggot noodles is influenced by the characteristics of the raw materials used, particularly the composition of maggot flour and wheat flour as the main ingredients. Maggot flour has been reported to have a relatively low moisture content of 2.60% [3], which contributes to reducing the overall moisture content of the final product. Meanwhile, the wheat flour used as a raw material complies with the quality standard SNI 3751:2018, which sets a maximum moisture content of 14.5%, indicating that it is within a safe range for use in dried noodle formulations [30].

Low moisture content in dried noodles plays an important role in determining product quality and shelf life. Reduced moisture levels can inhibit the growth of spoilage and pathogenic microorganisms and slow down chemical and enzymatic reactions that may lead to quality deterioration [31]. In addition, appropriate moisture content contributes to improved textural stability, reduces brittleness, and helps maintain the sensory characteristics of the noodles during storage. Therefore, the moisture content of maggot noodles that meets SNI standards indicates that this product has strong potential as a safe, stable, and viable dried food product. Furthermore, maggot noodles can be further developed as an alternative insect protein–based noodle product with favorable nutritional value and extended shelf life.

Ash sontent of Maggot Black Soldier Fly Larvae Noodles

The ash content obtained in this reserach reached 5.3%, which is strongly influenced by the mineral composition of the raw materials used in the formulation. BSFL flour is known to contain various essential minerals, including potassium (K), sodium (Na), calcium (Ca), copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), and phosphorus (P) [11]. Based on these nutritional characteristics, maggot noodles show considerable potential to be developed as a food product for stunting prevention programs. This potential is attributed to the high protein content of the substituted ingredient, as well as its substantial mineral and amino acid profiles, which are beneficial for supporting growth and overall health.

The incorporation of BSFL-based ingredients represents a strategic approach in functional food development to improve protein intake among children affected by stunting, thereby contributing to efforts to reduce stunting prevalence in Indonesia. In addition, the development of maggot noodle products is expected to support sustainable food systems by addressing food waste issues through the utilization of insects such as BSFL as alternative and environmentally friendly food resources.

4. Conclusion

Maggot noodles represent an innovative dried noodle product formulated through the substitution of Black Soldier Fly larvae (BSFL) flour as a potential solution to improve protein intake among children affected by stunting. Sensory evaluation results indicated that the best treatment was obtained in formulation M2, with a wheat flour to BSFL flour ratio of 50:50. Proximate analysis of the selected formulation showed an average protein content of 23.3%, moisture content of 12.9%, and ash content of 5.3%. The incorporation of BSFL flour as a food ingredient represents a strategic approach in the development of functional food products aimed at enhancing dietary protein intake in children with stunting, thereby contributing to the reduction of stunting prevalence in Indonesia.

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