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The Effect of Moringa Leaf Powder and Egg Supplementation on Nutritional Status and Appetite: A Quasi-Experimental Study in Undernourished Children.

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ABSTRACT

Undernutrition among children under five remains a major public health problem in Indonesia, particularly in East Nusa Tenggara Province. According to the 2024 Health Profile of East Nusa Tenggara Province, the prevalence of undernourished (wasted) children in South Central Timor Regency increased from 5.1% in 2019–2020 to 9.7% in 2024, indicating a persistent burden of acute malnutrition. While plant-based, nutrient-dense foods such as *Moringa oleifera* leaf powder have been widely promoted, evidence on their effectiveness when combined with high–biological-value animal protein, particularly eggs, remains limited. This study aimed to assess the effect of combined moringa leaf powder and egg supplementation on appetite and nutritional status among undernourished children aged 36–59 months. A quasi-experimental study with a control group was conducted from May to July 2025 in the Batuputih Health Center area. Forty undernourished children (weight-for-age Z-score −3 to −2 SD) were allocated to an intervention group (15 g/day moringa leaf powder plus one egg) or a control group (one egg only) for 60 days. Appetite was assessed using the Children's Eating Behaviour Questionnaire (CEBQ), and nutritional status was evaluated using WHO anthropometric indices Significant improvements in weight-for-age and weight-for-height were observed in both groups ($p < 0.05$). However, a significant increase in appetite was found only in the intervention group ($p = 0.039$), while no significant change was observed in height-for-age. The integration of moringa leaf powder with egg-based animal protein effectively improves appetite and short-term nutritional status, supporting weight-for-age and appetite as the most sensitive indicators for short-term nutrition programs, while linear growth requires longer intervention periods.

Key Messages:

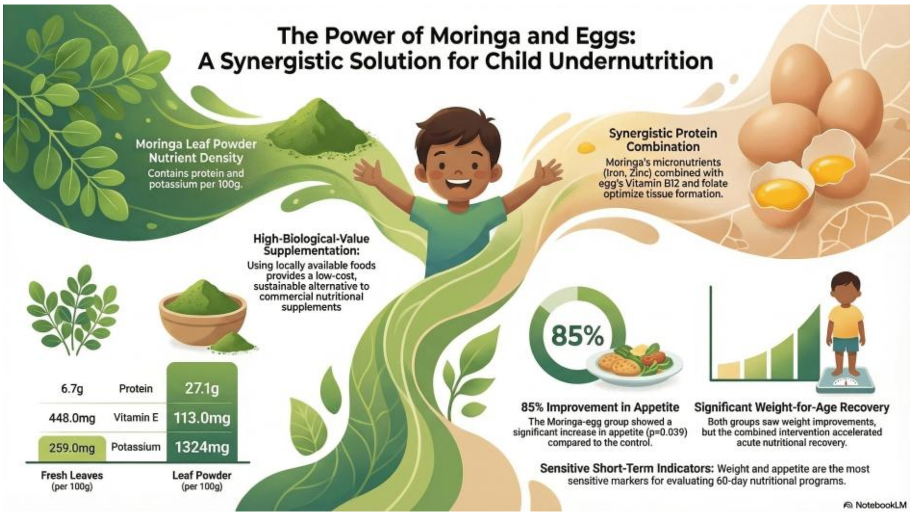
- Combining Moringa oleifera leaf powder with egg-based animal protein significantly improves appetite and short-term nutritional indicators among undernourished children.
- Improvements were most evident in weight-for-age and appetite, confirming these indicators as the most sensitive outcomes for evaluating short-term nutrition programs.
- Locally available, food-based interventions integrating plant and animal protein sources offer a feasible, low-cost, and programmatically relevant strategy for addressing acute child undernutrition in resource-limited settings.

Commented [RV1]: There is a contradiction between the abstract and the Results section that needs correction. The abstract states there were **"no significant changes"** in weight-for-height. However, the Results section later states that post-intervention analysis indicated a **significant difference** in Body Mass Index (BMI) between the groups ($p = 0.037$) and that supplementation **successfully lowered the BMI ratio** in the intervention group ($p = 0.011$). The abstract should be updated to reflect these significant BMI findings.

Include Intervention Duration: Mentioning that the intervention lasted **60 days** is crucial context for understanding why changes in linear growth (height-for-age) were not observed.

Refine the Conclusion: The abstract concludes by encouraging the use of moringa, but it could be strengthened by specifically mentioning that Weight-for-Age and appetite are the most **appropriate indicators for short-term programs**, as suggested in the study's formal conclusion

GRAPHICAL ABSTRACT



INTRODUCTION

Undernutrition in young children remains a significant global health challenge, with profound long-term consequences for human resource development. Despite various global health initiatives, the issue persists, particularly in low- and middle-income countries. According to the World Health Organization (WHO), an estimated 149.2 million children under five years old globally are affected by stunting, and 45.4 million suffer from wasting, a severe and life-threatening form of malnutrition (1). In Indonesia, undernutrition remains a persistent issue, with the Ministry of Health reporting that 21.5% of children under five are stunted as of 2023, only a slight decrease from 21.6% in 2022. This figure still falls short of the national target of 14% set for 2024 (2). Riskesdas 2018 data indicate that the prevalence of underweight and severely underweight children under five in Indonesia reached 17.7%, with East Nusa Tenggara (NTT) recording the highest prevalence at 29.5%(3). According to the 2024 Health Profile of East Nusa Tenggara Province, South Central Timor Regency showed a fluctuating yet overall increasing trend in the prevalence of undernourished (wasted) children under five (weight-for-height Z-score < -2 SD to -3 SD), remaining at 5.1% in both 2019 and 2020, declining slightly to 4.9% in 2021, rising to 6.4% in 2022, increasing further to 9.0% in 2023, and reaching 9.7% in 2024 (4).

This problem stems largely from a lack of adequate nutrition in the early stages of life. Adequate nutrition during the "golden age," the first five years of life, is crucial for supporting children's physical, cognitive, and emotional development, which ultimately affects their future quality of life (5). Malnourished children often experience reduced appetite due to factors like micronutrient deficiencies, gastrointestinal disturbances, and impaired immune responses, further exacerbating their nutritional deficiencies. Previous studies have indicated that appropriate nutritional interventions can improve appetite and enhance nutritional status in stunted children, thereby promoting better food intake (6, 7).

Despite these efforts, there are gaps in current knowledge, particularly regarding the efficacy of specific interventions. While various nutritional supplements have been explored, there is limited research on the combined effects of moringa leaf powder and animal protein sources on the nutritional status of undernourished children. Moringa, known as the "miracle tree," is a rich source of protein, vitamins, and minerals, and its dried leaves are recognized for their ability to improve nutritional intake. Studies have shown that moringa leaf powder can enhance the nutritional status of malnourished children, yet its combined effect with protein sources such as eggs remains largely unexplored (8, 9).

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Moringa oleifera is a nutrient-dense plant rich in protein, vitamins, and minerals that support growth and immune function, as highlighted by Gopalakrishnan et al. (2016). However, plant-based proteins may have limitations in digestibility and essential amino acid completeness. Therefore, moringa was combined with eggs, a high–biological-value animal protein source rich in vitamin B12, folate, and choline, which are critical for tissue formation, immune function, and appetite regulation. This combination is hypothesized to exert synergistic effects in improving appetite and nutritional status among undernourished children(11). Eggs also provide bioavailable zinc and vitamin B12, which play essential roles in immune maturation and infection resistance, factors closely linked to appetite and growth in undernourished children(12).

This study seeks to fill this gap by evaluating the impact of combining moringa leaf powder with eggs on the nutritional status and appetite of undernourished children in the Batuputih Health Center's working area in South Central Timor Regency. The objective is to assess how this combination could potentially improve both appetite and overall nutritional status in children, particularly in regions where malnutrition remains a critical concern. This research aims to provide actionable insights for nutritional interventions tailored to the unique needs of children in undernourished communities.

METHODS

This study was conducted in the working area of Batuputih Health Center, South Central Timor Regency, East Nusa Tenggara Province. The research was carried out from May to July 2025. The study employed a quasi-experimental design with a pretest-posttest with control group approach. This design was chosen because it allows the researcher to evaluate the effectiveness of the intervention in a situation where pure random assignment randomized controlled trial is not feasible, while still maintaining internal validity through the inclusion of a control group. The sample size was calculated using the Lemeshow formula for comparing two means, with a 95% confidence level and 80% power, then increased by 20% to account for potential dropout.

Based on the Lemeshow formula, the sample size was calculated as follows:

$$n = \frac{N.(Z_{1-2a/2p})^2.p.q}{d^2(N-1) + (Z_{1-2a/2p})^2.p.q}$$

$$n = \frac{58.(1{,}96)^2.0{,}08\ .0{,}92}{0{,}1^2(68-1) + (1{,}96)^2.0{,}08.0{,}92}$$

$$n = \frac{16{,}3}{0{,}95} = 17 + 20\% = 20$$

The target population of this study consists of undernourished children aged 36-59 months in the Batuputih Health Center area, South Central Timor Regency, East Nusa Tenggara. The sample included 40 children, with 20 subjects in the intervention group and 20 in the control group. Purposive sampling was used with inclusion criteria: children residing in the area, with a weight-for-age Z-score between -3 SD and -2 SD (WHO standards), no chronic or congenital diseases, and parental consent. Primary data was collected through anthropometric measurements, and 24-hour dietary recall interviews by trained researchers. The intervention group received 15 grams of moringa leaf powder combined with one egg daily, while the control group received only one egg daily. The intervention lasted for 60 days.

The nutritional potential of *Moringa oleifera* is demonstrated by its high concentration of macro- and micronutrients, as presented in Table 1.

Table 1. Nutrient Composition of Moringa oleifera Leaves in Fresh, Dried, and Powdered Forms (per 100 g) (10)

Nutrient	Fresh Leaves	Dried Leaves	Leaf Powder
Energy (kcal)	92,0	329,0	205,0
Protein (g)	6,7	29,4	27,1
Fat (g)	1,7	5,2	2,3
Carbohydrate (g)	12,5	41,2	38,2
Fiber (g)	0,9	12,5	19,2
Vitamin B1 (mg)	0,06	2,02	2,64
Vitamin B2 (mg)	0,05	21,3	20,5

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Nutrient	Fresh Leaves	Dried Leaves	Leaf Powder
Vitamin B3 (mg)	0,8	7,6	8,2
Vitamin C (mg)	220,0	15,8	17,3
Vitamin E (mg)	448,0	10,8	113,0
Magnesium (mg)	42,0	448,0	368,0
Phosphorus (mg)	70,0	252,0	204,0
Potassium (mg)	259,0	1236,0	1324,0

The selection of moringa leaf powder was based on its high content of protein, vitamins, and minerals particularly iron, calcium, zinc, and vitamin A which play important roles in growth and hemoglobin formation. Moreover, moringa is a locally available, inexpensive, and easy-to-process food source, and its potential as an alternative nutritional intervention has been well-documented in various studies. The nutrient composition of moringa leaves is presented in Table 1. Eggs were chosen as a source of animal protein with high biological value, rich in iron, vitamin B12, folate, and choline, which are essential for the immune system and tissue formation. The combination of moringa leaf powder and eggs is expected to provide a synergistic effect between plant and animal proteins and increase iron bioavailability. A 60-day intervention period was determined to evaluate the initial response to supplementation, which is considered sufficient to detect changes in nutritional status as an early indicator of nutritional improvement while maintaining participant compliance.

Primary data were collected through anthropometric measurements, appetite questionnaires, and 24-hour dietary recall interviews conducted by trained researchers. Children in the intervention group received moringa leaf powder (*Moringa oleifera*) at a dose of 15 g/day mixed into daily foods, combined with one hen's egg per day. The control group received one hen's egg per day without moringa supplementation. The intervention was administered at home under parental or caregiver supervision, following standardized instructions, for 60 consecutive days. Compliance was monitored through daily checklists completed by caregivers, verified during home visits, and by periodic collection of used moringa packaging.

Primary outcomes included appetite and nutritional status. Appetite was assessed using the Children's Eating Behaviour Questionnaire (CEBQ). Nutritional status was determined by measuring body weight and height using calibrated instruments (SECA 874 digital scale, 0.1 kg precision; microtoise, 0.1 cm precision). Dietary intake was assessed using the multiple-pass 24-hour dietary recall method, conducted five times on non-consecutive days. The first recall represented baseline intake, while the second to fifth recalls were averaged to estimate dietary intake during the intervention period.

Data were analyzed using SPSS. Normality was assessed using the Shapiro–Wilk test. Paired *t*-tests and independent *t*-tests were applied for normally distributed data to assess within- and between-group differences, respectively. Nonparametric alternatives (Wilcoxon signed-rank and Mann–Whitney U tests) were used when normality assumptions were violated. Statistical significance was set at $\alpha = 0.05$.

This study received ethical approval from the Health Research Ethics Committee, Faculty of Medicine, Diponegoro University, under approval number 084/EC/KEPK/FK-UNDIP/IV/2025.

RESULTS

This study involved 40 undernourished toddlers, evenly divided into the control and intervention groups. The majority of parents were farmers (57.5%) and had a secondary school education (42.5%) or a primary school education (37.5%). Approximately 67.5% of families reported monthly incomes below IDR 1,000,000. Gender, immunization status, and exclusive breastfeeding were relatively balanced between the two groups. Statistical analysis of the baseline characteristics, including age, revealed no significant differences between the control and intervention groups at the start of the study (Table 2). This indicates that both groups are comparable.

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Table 2. Characteristics of the Study Subjects

Variable	Control (n=20)	Intervention (n=20)	Total (n=40)
Age (months)	45.15 ± 5.8	46.90 ± 5.9	46.03 ± 5.8
Gender			
Female	12 (60.0%)	9 (45.0%)	21 (52.5%)
Male	8 (40.0%)	11 (55.0%)	19 (47.5%)
Parent's Occupation			
Farmer	11 (55.0%)	12 (60.0%)	23 (57.5%)
Merchant	2 (10.0%)	2 (10.0%)	4 (10.0%)
Employee	2 (10.0%)	2 (10.0%)	4 (10.0%)
Laborer	3 (15.0%)	2 (10.0%)	5 (12.5%)
Fisherman	2 (10.0%)	1 (5.0%)	3 (7.5%)
Worker	0	1 (5.0%)	1 (2.5%)
Parent's Education			
Completed Primary School	7 (35.0%)	8 (40.0%)	15 (37.5%)
Completed Secondary School	8 (40.0%)	9 (45.0%)	17 (42.5%)
Completed High School	3 (15.0%)	3 (15.0%)	6 (15.0%)
Did Not Complete Primary School	2 (10.0%)	0	2 (5.0%)
Immunization			
Complete	20 (100%)	20 (100%)	40 (100%)
Incomplete	0	0	0
Exclusive Breastfeeding			
Complete	20 (100%)	20 (100%)	40 (100%)
Incomplete	0	0	0
House Type			
Emergency	5 (25.0%)	0	5 (12.5%)
Semi-permanent	12 (60.0%)	10 (50.0%)	22 (55.0%)
Permanent	3 (15.0%)	10 (50.0%)	13 (32.5%)
Family Income			
< IDR 1 million	15 (75.0%)	5 (25.0%)	20 (50.0%)
> IDR 1 million	5 (25.0%)	8 (40.0%)	13 (32.5%)
Nutritional Status (WFA)			
Underweight	20 (100%)	20 (100%)	40 (100%)

Nutritional status analysis focused on three anthropometric indices: weight-for-age (WFA), height-for-age (HFA), and Weight-for-Height (WFH). The pre- and post-intervention measurements, as well as the comparisons between groups, are presented in Table 3.

Table 3. Nutritional status before and after intervention in the control and intervention groups.

Variable	Control Group (n = 20)	Intervention Group (n = 20)	p-value
Nutritional Status			
Weight-for-Age Index (WFA)			
Before	-2,36 ± 0,35***	-2,44 ± 0,32***	0,427^{a}
After	-1,85 ± 0,67***	-1,77 ± 0,36***	0,436^{a}
p-value	< 0,001^{d*}	0.002^{d*}	
Height-for-Age Index (HFA)			
Before	-2,09 (-3,15– (-0,41))**	-2,39 (-3,43- (-1,14)**	0,561^{c}
After	-2,09 (-3,15- 0,41)**	-2,39 (-3,43- 0,30)**	0,386^{c}
p-value	1,000^{b}	0,157	
Weight-for-Height (WFH)			
Before	-1,55 (-3,38- (-0,31))**	-1,82 (-3.08- (-1,01)**	0,190^{a}
After	-1,68 (-3,38- (-0,31))**	-1,71 (-3,08- 0,82)**	0,882^{c}
p-value	0,003^{b*}	<0,001^{b*}	

^{a}: *Independent T-test,* ^{b}: *wilcoxon* ^{c}: *Man-whitney* ^{d}: *Paired T-test ,* **:signifikan* $p < 0,05$ ****:mean±SD* ***:median (min-max)*

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Table 4. Changes in appetite before and after the intervention.

Appetite	Control Group (n = 20)	Intervention Group (n = 20)	p-value
Before	2,00 (1,00 -2,00)*	0,90 (0,70 – 1,10)*	1,000[a]
After	1,50 (1,00 -2,00)*	0,95 (0,70 – 1,20)*	**0,035[a]**
p-value	0,424[b]	**0.039[b]**	

*median(min-max), [a]: *Chi-square,* [b]*: McNemar,* *:*signifikan p < 0,05*

Change in Weight-for-Age Index (WFA)

For WFA, both groups showed a statistically significant improvement after the intervention. In the control group, the mean WFA z-score increased from −2.36 ± 0.35 to −1.85 ± 0.67 ($p < 0.001$). Similarly, the intervention group demonstrated a significant increase from −2.44 ± 0.32 to −1.77 ± 0.36 ($p = 0.002$). However, no significant differences were observed between the control and intervention groups either at baseline or post-intervention ($p > 0.05$).

The absence of a significant between-group difference in WFA and WFH suggests that egg supplementation alone already provides substantial nutritional benefits. Nevertheless, the greater proportion of appetite improvement observed in the intervention group indicates that moringa leaf powder may exert additional effects through appetite modulation and micronutrient adequacy.

Change in Height-for-Age Index (HFA)

The results presented in Table 3 indicate no significant change in the nutritional status of the group consuming moringa leaf powder, as measured by the HFA index before and after the intervention. Regarding HFA, no significant changes were detected in either group following the intervention. The median HFA z-score in the control group remained at −2.09 (range: −3.15 to −0.41; $p = 1.000$), while the intervention group showed a median of −2.39 (range: −3.43 to −0.30; $p = 0.157$). Intergroup comparisons at baseline and post-intervention also revealed no statistically significant differences ($p > 0.05$).

Change in Weight-for-Height (WFH)

Analysis of the weight-for-height index (BMI) revealed a significant difference between the intervention and control groups. For WFH, significant within-group changes were observed in both groups. The control group showed a significant change in median WFH z-score ($p = 0.003$), while the intervention group exhibited a more pronounced change ($p < 0.001$). Nonetheless, comparisons between the control and intervention groups before and after the intervention did not demonstrate statistically significant differences ($p > 0.05$).

Appetite

Analysis of appetite showed a significant difference between the intervention and control groups. In the intervention group, a statistically significant increase in appetite was observed from pre- to post-intervention ($p = 0.039$). In contrast, no significant change was found in the control group ($p = 0.424$). Furthermore, post-intervention analysis revealed a statistically significant difference in appetite scores between the intervention and control groups ($p = 0.035$).

Figure 2 shows changes in appetite before and after the intervention. In the control group, 80% of participants showed no change, whereas only 20% experienced improvement. Conversely, 85% of participants in the intervention group demonstrated improved appetite, with 15% showing no change.

A randomized controlled trial in India reported that supplementation with *Moringa oleifera* leaf powder in children with severe acute malnutrition significantly improved body weight and feeding outcomes ($p < 0.05$). The authors attributed these effects to increased nutrient density, improved nutrient absorption, and reduced gastrointestinal discomfort. Although appetite was not measured using the Children's Eating Behaviour Questionnaire (CEBQ), the observed increases in food intake and feeding acceptance are conceptually consistent with the "enjoyment of food" subscale, supporting the role of *Moringa oleifera* leaf powder in enhancing appetite and nutritional recovery among malnourished children(13, 14).

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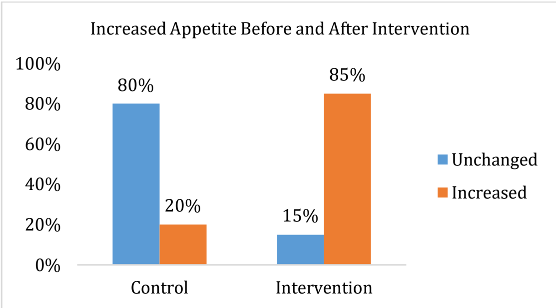

Figure 1 Increased Appetite Before and After Intervention

DISCUSSION

Characteristics

The balanced characteristics of age and initial nutritional status reinforce the validity of the comparison between the effects of moringa leaf powder in the intervention and control groups. The results indicate that supplementation with moringa leaf powder can improve the nutritional status of toddlers, as reflected in the increased weight and other nutritional parameters. This change in the intervention group can be attributed to the supplementation (14).

An analysis by gender revealed a higher prevalence of undernutrition in girls compared to boys. This finding is consistent with the theory that boys often receive higher priority in food allocation due to their higher physical activity levels. A previous study in Ghana confirmed this, showing that girls are at greater risk of nutritional issues compared to boys (15, 16). The majority of parents had low levels of education, which aligns with research in Indonesia indicating that parental education, especially that of mothers, is strongly associated with the quality of child nutrition.

In addition, most households in both groups were characterized by low socio-economic status, with 75% of families in the control group and 25% in the intervention group reporting monthly incomes below IDR 1 million. This economic constraint underscores the relevance of moringa leaf powder as a locally available, culturally acceptable, and low-cost nutritional intervention, particularly for low-income families. The majority of parents also had low educational attainment, in line with evidence from Indonesia showing that parental education especially maternal education is strongly associated with child nutritional quality. Ensuring homogeneity across these socio-demographic characteristics helps minimize potential confounding and strengthens the internal validity of the study (17-19).

Weight-for-Age Index (WFA)

The use of moringa leaf powder as a nutritional supplement for individuals with low nutritional status has shown promising results in various studies. Moringa is known for its high content of protein, vitamin A, vitamin C, calcium, and iron, all of which are essential for growth and weight maintenance. Several studies have indicated that supplementation with moringa leaf powder can improve nutritional status, although not always statistically significant.

A study by Zongo (2013) in Burkina Faso involved 110 children with poor nutritional status who were given 10g of moringa leaf powder per day. The results showed an average daily weight gain of 8.9 g/kg/day in the intervention group, compared to 5.7 g/kg/day in the control group (20, 21). Irwan (2020) reported the effects of an intervention using moringa seed and leaf biscuits on weight gain and nutritional status after 90 days. A significant weight gain was observed in both intervention groups, with p-values < 0.05, while energy and protein intake had no significant effect ($p > 0.05$). This study was conducted in the working area of Tampa Padang Health Center in Mamuju Regency (22).

Another study by Cahyaningsih (2024) in Indonesia, using a quasi-experimental design with 30 toddlers, showed that after three weeks of feeding with moringa-enriched food, there was an average weight gain of 2.01 kg and an increase in height of 1.3 cm. These changes suggest that moringa leaves are

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effective as a nutritional supplement to prevent stunting in toddlers (23). Moringa leaf powder, as described by Fitriani (2024), contains nutrients that can contribute to improving nutritional status, particularly in supporting growth and weight maintenance for individuals with low nutritional status. Although the p-values obtained did not show significant differences between the control and intervention groups, the results still indicate that moringa leaf powder may have an effect on nutritional status (24).

The significant improvement in weight-for-age (WFA) observed in both the intervention and control groups highlights the contribution of egg supplementation as a standalone intervention in promoting short-term nutritional recovery. Eggs are a high–biological value food, providing complete essential amino acids and key micronutrients such as vitamin B12 and folate, which are essential for cellular growth, erythropoiesis, and energy metabolism. In contexts of pronounced undernutrition, even a modest addition of animal-source protein, such as one egg per day, can substantially improve protein quality and micronutrient intake, thereby supporting weight gain and explaining the significant within-group increases in WFA observed in both groups ($p < 0.05$).

This “egg effect” is also reflected in the changes observed in weight-for-height (WFH), an indicator of acute nutritional status (wasting) that is particularly sensitive to short-term dietary interventions. In the present study, WFH improved significantly from baseline within both the control and intervention groups ($p < 0.05$), indicating that egg supplementation alone was sufficient to promote early weight recovery relative to height. However, the comparison between groups did not reveal a statistically significant difference in WFH either before or after the intervention ($p > 0.05$), suggesting that both interventions were effective in improving acute nutritional status over the 60-day period. Notably, the greater magnitude of WFH improvement observed in the intervention group suggests a potential additive benefit of moringa leaf powder when combined with eggs. While eggs primarily address protein and selected micronutrient deficiencies, moringa leaf powder provides complementary micronutrients, including iron, zinc, vitamin A, and vitamin C, which support nutrient absorption, immune function, and anabolic processes. This nutritional complementarity may enhance nutrient utilization and accelerate recovery from wasting, even if the between-group difference did not reach statistical significance within the study duration.

Height-for-Age Index (HFA)

Moringa oleifera, known for its rich nutritional content, including vitamins, minerals, and proteins essential for body metabolism, has shown significant effects in enhancing nutrient intake in individuals with poor nutritional status (25). In this study, no significant change in height-for-age (HFA) was observed after the 60-day intervention. This finding contrasts with Nastiti (2025), who reported a 2.9 cm increase in height among toddlers receiving moringa-fortified diets. The discrepancy is likely attributable to differences in intervention duration and the biological characteristics of HFA as an indicator of chronic malnutrition (stunting). Linear growth responds slowly to nutritional interventions and typically requires several months or longer to demonstrate measurable change. Therefore, the absence of a significant HFA improvement in this study does not indicate a lack of effectiveness of moringa leaf powder, but rather reflects the limited sensitivity of HFA to short-term nutritional interventions. These findings underscore the need for longer intervention periods to evaluate the impact of moringa supplementation on linear growth(26).

Weight-for-Height (WFH)

The improvement in weight-for-height (WFH) observed after the 60-day intervention indicates a positive effect of the combined moringa leaf powder and egg supplementation on acute nutritional status (wasting). WFH is known to be highly responsive to short-term nutritional interventions, as it reflects recent changes in body weight relative to height rather than long-term linear growth (1). In this study, significant within-group improvements in WFH were observed following the intervention, although no significant differences were detected between the intervention and control groups, suggesting that both dietary approaches contributed to short-term weight recovery.

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The greater magnitude of change in the intervention group may be explained by the synergistic nutritional effects of eggs and moringa leaf powder. Eggs provide high-quality animal protein with a complete essential amino acid profile, while moringa leaf powder supplies key micronutrients such as iron, zinc, vitamin A, and vitamin C that support energy metabolism, immune function, and protein synthesis (27, 28). This nutritional synergy likely enhances nutrient utilization and facilitates rapid weight gain during recovery. Consistent with these findings, Sakung (2024) reported significant improvements in body weight among malnourished children receiving moringa supplementation, with more pronounced effects on acute nutritional indicators than on linear growth, particularly when moringa was combined with high-quality protein sources (29).

Appetite

The improvement in appetite observed in this study may be explained by the synergistic effects of key micronutrients in moringa leaf powder, particularly zinc, iron, and vitamin C. Zinc plays an essential role in taste perception and appetite regulation; therefore, improved zinc intake may restore taste sensitivity and increase food palatability in malnourished children (30). In addition, vitamin C in moringa enhances the absorption of non-heme iron from both moringa leaves and eggs, helping to correct iron deficiency, which is commonly associated with fatigue and poor appetite. Improved iron status may indirectly support appetite recovery by enhancing metabolic efficiency. Furthermore, the antioxidant and anti-inflammatory properties of moringa bioactive compounds may improve neuroendocrine regulation of eating behavior (27). These mechanisms are consistent with previous findings showing that moringa-based food fortification significantly improves appetite in toddlers (31).

Strengths and Limitations of the Study

This study has several strengths, including the use of a controlled design, standardized appetite assessment using the Children's Eating Behaviour Questionnaire (CEBQ), and the application of locally available food-based interventions. However, limitations include the relatively short intervention duration and the absence of biochemical indicators, which may limit conclusions regarding micronutrient status and long-term growth outcomes.

CONCLUSION

The combined supplementation of moringa leaf powder and eggs effectively improved acute nutritional status among undernourished toddlers, as indicated by significant improvements in weight-for-age and weight-for-height, while height-for-age remained unchanged over the 60-day intervention. These findings indicate a synergistic effect of locally available plant-based moringa and high–biological-value animal protein in enhancing appetite and short-term nutritional recovery. Given the low-income context of the study population, this intervention represents a feasible, culturally appropriate, and cost-effective food-based strategy for resource-limited settings such as East Nusa Tenggara. Longer intervention periods and the inclusion of biochemical markers are recommended for future studies to evaluate effects on linear growth and underlying mechanisms.

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CONFLICTS OF INTEREST

The author has no conflict of interest.

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