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Quality Evaluation and Acceptability of Improved 'Luam-Nahan' Porridge Flour Developed from Maize, Cassava, Soybean, and Jatropha Tanjorensis for Preschool Children

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ABSTRACT

Background: Preschool age is critical for continued growth and development in young children. This study evaluates the nutritional quality and acceptability of nutritionally enhanced *luam-nahan* Porridge flour for preschool children in low and middle-income countries (LIMCs). **Methods:** quality protein maize (QPM), Provitamin-A Cassava, Soybean and *Jatropha tanjorensis* leaves underwent pre-treatments including steeping, fermentation, and drying, then milled into flour and blended into ratios:44:44:10:2, 39:39:20:2, 34:34:30:2, and 29:29:40:2. At a ratio of 50:50, white maize and cassava mixture was also prepared as a control for comparison. The mixture was evaluated for proximate composition, energy, vitamin content, and functional properties using AOAC methods. Sensory acceptability was assessed by 30 caregiver-preschooler pairs using nine-point hedonic scale for caregivers and three-point scale for preschoolers. Data were analyzed using one-way ANOVA and LSD test, and results were reported as means and standard deviations (P>0.05), indicating no statically significant difference among the samples. **Results:** Proximate analysis revealed higher protein (25.48 g/100 g) and fat (6.02 g/100 g) in the 29:29:40:2 mixture, with moisture content within the recommended limits. Vitamin A and B levels exceeded recommended dietary allowance in mixtures, and mixture 44:44:10:2 had the highest amount of vitamin A (1071.29 iu). Functional properties, such as bulk density, decreased with soybean content. Sensory evaluation favored the control for taste, while mixture 44:44:10:2 was the most acceptable improved mixture. **Conclusion:** Enhanced protein, vitamin content and functional properties of the improved *Luam-Nahan* porridge flour mixtures could help to meet the nutritional needs of preschoolers in LIMC. Mixture 44:44:10:2 ensured optimal taste and acceptability, making it a viable option for reducing malnutrition.

Introduction

Undernutrition of essential proteins, calories and micronutrients among preschoolers is a pressing global concern requiring urgent attention especially in low and middle-income countries

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(LIMCs) like Nigeria (Pius *et al.*, 2022) and can lead to long-lasting physical and cognitive impairments, compromising a child's overall survival, development, and future potential (Adepoju and Ajayi, 2016, World Health Organization, 2024).

Preschool age is a transitional period when children move from breastfeeding and complementary feeding to eating family meals, which are often primarily composed of starch-based staples. These meals tend to be low in protein, calories, and essential micronutrients, particularly vitamin A (Nwankwo *et al.*, 2022). This nutritional deficiency can hinder growth and development and increase the risk of mortality from common childhood illnesses due to weakened immunity.

Luam-Nahan is a traditional Nigerian porridge that is popular among the *Tiv* tribe and other ethnic groups in the North Central region of Nigeria, such as the *Idoma* and I*gede*. In these groups, it is called *Ona* and *Ogidi*, respectively. This dish is also recognized in East African countries, where it is referred to as *Ugali* or *Nsima*. It is a mixture of cereal and cassava flour, commonly eaten with thick soups like okra due to its affordability, soft texture and ease of swallowing by young children. *Luam-Nahan* primarily consists of carbohydrates (Dendegh *et al.*, 2021), which means it does not fulfill the protein, calorie, and micronutrient requirements for preschoolers. However, by increasing its consumption, there is potential to enhance the nutritional status and health of preschoolers.

Traditional maize (*Zea mays Linaeus.*) is deficient in lysine and tryptophan, posing serious nutritional deficiency especially in young children, in countries with high human consumption (Wossen *et al.*, 2023). Quality protein maize (QPM) is an improved maize variety which contains twice the amount of lysine and tryptophan, thereby increasing protein quality of the maize. It also has higher content of other nutrients such as niacin and calcium (Choudhary and Choudhary, 2020, Nuss and Tanumihardjo, 2011).

Cassava (*Manihot esculenta*) is the third largest carbohydrate staple food in Sub-Saharan Africa (Ikuemonisan and Akinbola, 2019). However, it is predominantly high in carbohydrates and fiber, which puts populations that rely on it at risk of protein and micronutrient deficiencies (Gegios *et al.*, 2010, Stephenson *et al.*, 2010). Due to the significant prevalence of vitamin A deficiency (VAD) among these cassava-consuming populations, provitamin A cassava was introduced to help prevent and control VAD, particularly in Sub-Saharan Africa (Olatunde *et al.*, 2023). This enhanced variety contains 120 µg of provitamin A per 100 g (HarvestPlus, 2022) and has the potential to improve vitamin A status of consumers by providing up to 25% of their daily vitamin A requirement (Ariyo *et al.*, 2023, Olatunde *et al.*, 2023).

Soybean (*Glycine max*) is a leguminous plant that is cultivated globally for its edible beans (Terzic *et al.*, 2018). Soybeans contain over 36% protein, 30% carbohydrates, a significant amount of dietary fiber, vitamins, minerals, and 20% oil, making them one of the most important edible oil crops in the world (International Institute of Tropical Agriculture (IITA) 2023). In Nigeria, soybeans are crucial both nutritionally and economically due to their high protein and oil content. They have been utilized for many years in the country to fortify traditional and non-traditional starchy food with protein (Adelakun *et al.*, 2012).

Jatropha tanjorensis (j. tanjorensis) is a small succulent plant belonging to the family E*uphorbiaceae* known in Nigeria by common names such as *hospital-too-far* and *tree spinach* (Nwakwo *et al.*, 2022). This plant is relatively unknown and not commonly used as a vegetable in Nigeria. Its leaves are rich in essential nutrients, including iron, zinc, potassium, sodium, calcium, magnesium, and vitamin A (Chigozie *et al.*, 2018, Nwachukwu, 2018). Additionally, *J. tanjorensis* contains phytochemicals such as alkaloids and flavonoids, which contribute to its potential anti-microbial, anti-diabetic, antioxidant, and anti-inflammatory properties (Awote *et al.*, 2023, Imohiosen, 2023).

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The continuous consumption of traditional *Luam-Nahan* produced from a mixture of traditional white maize and white cassava increases the risk of several nutritional deficiencies among consumers, particularly preschool children. The utilization of QPM and provitamin A cassava as primary ingredients in the enhanced flour in addition to its enhancement with soybeans which is high in protein and *J. tanjorensis* leaves, rich in micronutrients would enhance protein quality especially lysine and tryptophan content and micronutrient content, particularly vitamin A, a micronutrient of public health significance in LMICs. The combination of these nutrient-rich food materials for a nutritional enhanced *Luam-Nahan* porridge flour, which will be more nutritious than the traditional mixture is therefore a crucial option for sustainable malnutrition prevention which will aid in improving the nutritional and health status of preschool children and other consuming populations. Hence, the study aimed to evaluate nutritional quality and acceptability of improved *Luam-Nahan* porridge flour made from QPM, Provitamin A Cassava, Soybean and *J. tanjorensis* leaves for preschool children.

Materials and Methods

Source of materials

QPM (BR9928-DMR-SRY) and Provitamin A cassava (TMS01/1371) were obtained from the Institute of Agricultural Research and Training (IAR &T) Ibadan, Oyo State. *Jatropa tanjorensis* leaves were obtained from Ikwe Forest Reserve in Igbor Benue State and authenticated at the Forestry Research Institute of Nigeria, Ibadan, Oyo State, with herbarium copy deposited with number NO.FHI.114048. Soybeans, white cassava (TME 419), and white corn (TZW,2005) were also obtained from Benue State from a private farm in Makurdi. Chemicals used for all analyses were of analytical reagent grade. Pictures of food materials used in this study are shown in **Figure 1**.

Sample preparation

Materials for this study were prepared as shown in **Figures 2** and **4** according to the methods of Beruk *et al*. and Onoja *et al*. (Beruk *et al*., 2015, Onoja *et al*., 2014) with modification (Igbua *et al*., 2019, Momoh *et al*., 2020, Toluwalope *et al*., 2018).

Flour blending

All food items were processed into their respective flour and the flour of all food materials were blended at various ratios to obtain five samples, including one control, as shown in **Table 1**.

Preparation of luam-nahan (stiff porridge)

Luam-nahan was prepared from the traditional and improved flour according to the method of Karim *et al*. (Karim *et al*., 2013) shown in **Figure 3**.

Figure 1. Food materials used for the development of improved *Luam-nahan* flour.

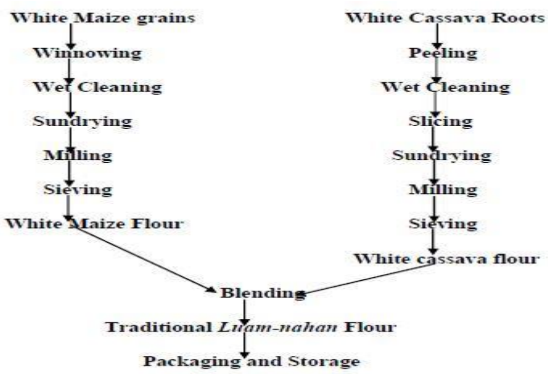

Figure 2. Flow chart for the production of traditional *Luan-nahan* flour.

Determination of proximate, energy, and vitamin composition of the flour

Moisture content, crude protein, crude fats, and ash were determined using (Association of Official Analytical Chemists, 2005). The carbohydrate

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content of the flours was determined using the carbohydrate by difference method, by subtracting the weight of moisture, protein, fats, fiber and ash from 100 while their gross energy was determined using the ballistic bomb calorimetric method. Beta-Carotene, B Vitamins, and Vitamin E determinations were done using the method of Adepoju and Daagema (Adepoju and Daagema, 2021.). All analyses were done in triplicates.

Determination of functional properties of the flour

Bulk density and pH were determined based on the method of Bankole et al. (Bankole *et al.*, 2013), water absorption capacity (WAC) by Adeoye et al. (Adeoye *et al.*, 2020), solubility index and swelling power by Adebowale et al. (Adebowale *et al.*, 2012).

Figure 3. *Luam-nahan* prepared from traditional and improved flour for sensory evaluation.

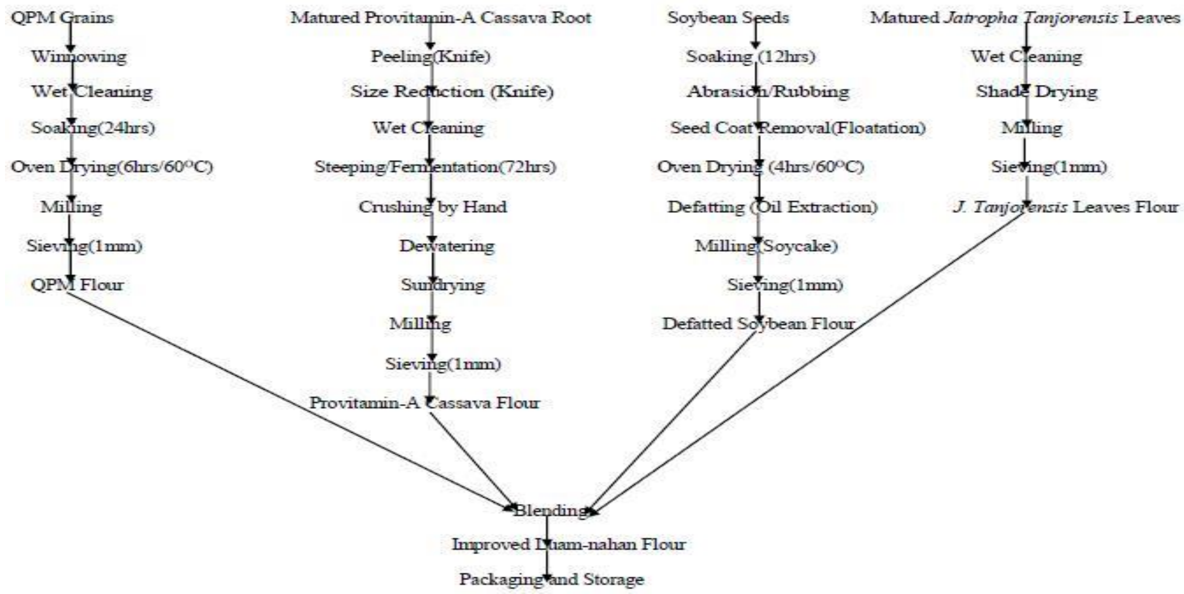

Figure 4. Flow chart for the production of improved *Luam-nahan* flour.

Table 1. Percentage of mixture formulation for the development of improved *Luam-Nahan* porridge flour.

Food materials	Samples				
	A	B	C	D	E
White maize flour	-	-	-	-	50
White cassava flour	-	-	-	-	50
QPM flour	44	39	34	29	-
Provitamin A cassava flour	44	39	34	29	-
Defatted soyabean flour	10	20	30	40	-
Jatropha tanjorensis leave flour	2	2	2	2	-
Total	100	100	100	100	100

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Sensory evaluation

Stiff porridge was prepared from each type of flour and evaluated for sensory attributes with the assistance of 30 mother-preschooler pairs (15 pairs from each location) from Makurdi and Daudu communities in Benue State. Sensory evaluation for caregivers was conducted using a 9-point hedonic scale (Iwe, 2002), while a three-point pictorial hedonic scale was used for preschool children, where 1=dislike, 2=neither like nor dislike, and 3=like (Food fact life, 2010).

Ethical considerations

Ethical approval for this research was obtained from the Ethics Committee of Afe Babalola University Ado-Ekiti (ABUAD), Ekiti State, Nigeria, with No ABUADHREC/26/04/2024/514. Informed consent was obtained from caregivers and verbal assent was received from the preschoolers for sensory evaluation of the improved *Luam-Nahan* flour.

Data analysis

The data were analyzed using Statistical Package for Social Sciences (SPSS.) V21 and Graphpad Prism V10.0 computer software. The data were subjected to Analysis of Variance (ANOVA) and Fisher's least significant difference (LSD) test at P-value>0.05 and presented as means and standard deviations.

Results

Proximate and energy composition

The proximate and energy values of traditional and improved *Luam-Nahan* flour, as shown in **Table 2**, indicated that all flour samples were low in moisture and crude fat. The traditional flour contained higher levels of crude fiber and carbohydrates, whereas the improved flour had greater amounts of moisture, crude protein, crude fat, ash, and gross energy. As the substitution level of defatted soybean flour increased, these parameters in the improved flour also rose. Notably, only the improved flour provided more than half of daily protein requirements and over a quarter of daily carbohydrate and energy needs for preschoolers.

Vitamin composition

Vitamin composition results of traditional and improved *Luam-Nahan* flour, presented in **Table 3**, indicated that conventional *Luam-Nahan* flour had the lowest levels of all vitamins. In contrast, vitamins in the improved flour increased with a higher percentage of soybean inclusion, except for provitamin A, which decreased as the soybean flour percentage increased. As a result, only the sample with a composition of 44% QPM flour, 44% provitamin A flour, 10% soybean flour, and 2% *J. tanjorensis* met half of the recommended dietary allowance (RDA) for vitamin A for preschool children. In addition, all improved flour samples provided more than half of the RDA for B vitamins and vitamin E for preschoolers.

Functional properties

Results of functional properties of traditional and improved *Luam-Nahan* flour, as shown in **Table 4**, indicated that there was an increase in pH, WAC, solubility index, and swelling power of improved *Luam-Nahan* flour as the inclusion of soybean flour increased. In contrast, traditional *Luam-Nahan* flour exhibited a higher bulk density, which decreased with an increase in soybean flour substitution from 10% to 40%. This decrease was statistically insignificant (P>0.05) among different flour samples.

Sensory attribute of traditional and improved Luam-Nahan flour

Results of sensory evaluation of traditional and improved *Luam-Nahan* flour by caregivers and preschool children, as shown in **Table 5** and **Figure 5**, indicated that the substitution of soybean and *J. tanjorensis* leaf flour in various improved flour samples affected all sensory parameters evaluated. There were significant differences in all the parameters assessed. *Luam-Nahan* with 10% soybean inclusion was the most acceptable option among formulations prepared using improved flour by caregivers, and it was also the most favoured by preschoolers.

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Table 2. Proximate and energy values of the traditional and improved *Luam-Nahan* flour (g/100 g).

Variable	Samples					USDA& USDHHS: RDA	FAO/WHO: RDA
	A	B	C	D	E		
Moisture (%)	7.26±0.01[b]	7.41±0.00[b]	7.67±0.01[a]	7.68±0.01[a]	7.18±0.29[b]	<14% (USDA)	15% MAX(FAO/CODEX)
Crude protein (g/100 g)	11.42±0.00[d]	14.83±0.02[c]	17.27±0.01[b]	25.48±0.00[a]	4.63±0.01[e]	13-19 g/day	14.5-17.5 g/day
Crude fat (g/100 g)	3.92±0.01[d]	4.41±0.01[c]	5.46±0.01[b]	6.02±0.02[a]	1.38±0.00[e]	27-25 g/day	<30% total calories
Crude fiber (g/100 g)	3.17±0.01[b]	1.40±0.01[c]	0.63±0.01[d]	0.37±0.03[e]	5.14±0.01[a]	14-17 (14g/1000 kcal)	15 g/day
Ash (g/100 g)	1.88±0.01[d]	2.06±0.01[c]	2.46±0.01[b]	2.86±0.01[a]	1.25±0.01[e]	-	-
Carbohydrate (g/100 g)	72.35±0.03[b]	69.89±0.23[c]	66.51±0.03[d]	57.59±0.03[e]	80.42±0.01[a]	130 g/day	At least 250 g/day
Gross energy (kcal/100g)	374.40±0.28[d]	377.77±0.04[c]	384.30±0.22[b]	386.50±0.37[a]	353.26±0.00[e]	1000-1400 kcal/day	1250-1550 kcal/day

Values with the same superscript on the same row are not significantly different (P> 0.05) based on one-way ANOVA and Fisher's LSD post-hoc test; Values are means±SD; United State Department of Agriculture and United State Department of Health and Human Services :Recommended Daily Allowance 2020-2025 (Snetselaar et al., 2021);: Food and Agricultural Organization and World Health Organization 2023 Updated Recommended Daily Allowance (Food and Agriculture Organization and World Health Organization, 2023) ; USDA moisture maximum percent for commercially packaged cereal grain and flour(United State Department of Agriculture (USDA), 2019); FAO CODEX standard for corn (Food and Agriculture Organization and World Health Organization, 1995).

Table 3. Vitamin composition of traditional and improved *Luam-Nahan* flour (mg/100g)

Vitamin	Samples					USDA & USDHHS: RDA	FAO/WHO: RDA
	A	B	C	D	E		
A (IU)	1071.29±88.08[a]	789.95±64.95[b]	667.31±54.86[c]	580.74±47.75[d]	173.14±14.23[e]	2000-3000 IU/day	1333.33 -1500 IU/day
B_6 g/100 g)	0.54±0.01[c]	0.59±0.01[b]	0.70±0.02[a]	0.72±0.02[a]	0.40±0.01[d]	0.5-0.6 mg/day	0.5-0.6 mg/day
B_9 (mg/100 g)	3.48±0.11[c]	5.34±0.16[b]	7.23±0.22[a]	7.32±0.10[a]	2.33±0.07[d]	150-200 mg/day	150-200 mg
B_{12} (mg/100 g)	0.63±0.01[d]	0.76±0.01[c]	1.06±0.02[b]	1.12±0.03[a]	0.58±0.03[e]	0.9-1.2 μg/day	0.9-1.2 μg
E (mg/100 g)	3.49±0.11[d]	5.34±0.16[c]	7.01±0.08[b]	7.32±0.09[a]	2.33±0.07[e]	6-7 mg/day	5.0 mg/day

Values with the same superscript on the same row are not significantly different (*P*>0.05) based on one-way ANOVA and Fisher's LSD post-hoc tests; Values are *means±SD.*

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Table 4. Functional properties of the traditional and improved *Luam-Nahan* flour.

Parameter	Samples				
	A	B	C	D	E
pH	5.67±0.02[b]	5.79±0.01[b]	5.85±0.02[c]	5.95±0.02[d]	5.52±0.03[a]
Bulk density (g/ml)	0.67±0.00[a]	0.66±0.01[a]	0.64±0.01[a]	0.62±0.01[a]	0.67±0.03[a]
Water absorption capacity (%)	2.75±0.07[b]	2.80±0.00[b]	3.15±0.07[c]	3.20±0.00[c]	2.00±0.00[a]
Solubility index (%)	2.08±0.03[a]	2.89±0.04[b]	3.23±0.12[c]	5.00±0.01[d]	2.08±0.02[a]
Swelling power (%)	0.28±0.04[b]	0.43±0.04[c]	0.43±0.04[c]	0.48±0.04[c]	0.18±0.04[a]

Values with the same superscript on the same column are not significantly different (P>0.05) based on one-way ANOVA and Fisher's LSD post-hoc test; Values are means±SD.

Table 5. Sensory evaluation of *Luam-Nahan* by caregivers.

Parameter	Samples				
	A	B	C	D	E
Color	7.73±0.83[b]	7.70±0.88[b]	7.07±1.28[c]	7.97±1.07[d]	8.47±1.20[a]
Aroma	7.47±1.04[b]	7.47±1.55[b]	6.87±1.45[c]	6.97±1.13[d]	8.20±1.13[a]
Taste	7.63±1.50[b]	7.50±0.86[c]	5.87±1.36[d]	5.83±1.42[d]	8.00±1.29[a]
Texture	7.27±1.60[b]	7.33±1.58[c]	6.50±1.66[d]	6.53±1.66[d]	7.87±1.38[a]
Ease of swallowing	8.07±1.20[b]	7.87±1.41[c]	7.37±1.71[d]	7.40±1.43[e]	8.43±1.50[a]
Mouldability	7.63±1.47[b]	7.77±1.22[c]	7.47±1.31[d]	7.37±1.79[e]	8.33±0.96[a]
General acceptability	8.13±1.31[b]	7.60±1.28[c]	6.90±1.47[d]	6.67±1.79[e]	8.53±0.97[a]

Values with the same superscript on the same row are not significantly different (P>0.05) based on one-way ANOVA and Fisher's LSD post-hoc test; Values are means±SD.

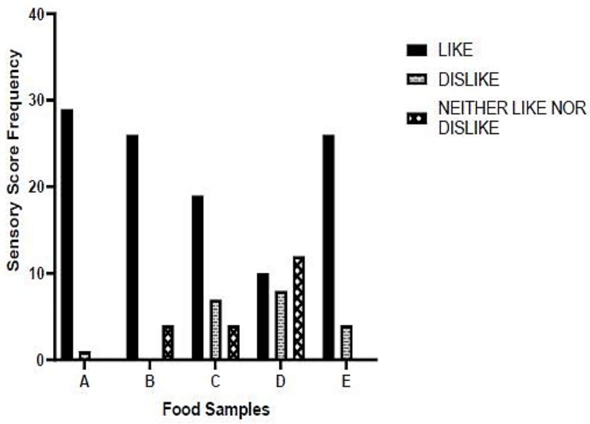

Figure 5. The sensory scores of *Luam-Nahan* by preschoolers.

Discussion

The study evaluated nutritional quality and acceptability of improved *luam-Nahan* porridge flour made from QPM, Provitamin-A Cassava, Soybean, and *J. tanjorensis* leaves for preschool children. The improved flour showed significant enhancement in their nutritional profiles compared to the traditional flour particularly in terms of protein and vitamin A, providing over half the RDA for preschoolers and exceeding the RDA for B vitamins. Soybean inclusion positively affected functional properties of the flour by decreasing their bulk densities and improving their WAC, solubility, and swelling power. Sensory evaluation indicated that the improved flour was generally well-accepted by both caregivers and preschool children with the 10% soybean inclusion flour mixture as the most preferred option.

Low moisture content of the flour in this study suggested a prolonged shelf life when packaged. This moisture level was also lower than what was reported by Igbua *et al.*, which may be due to differences in processing methods (Igbua *et al.*, 2019). Moreover, crude protein content increased with higher levels of soybean substitution, aligning with the findings of Adeoye *et al.* and Dendegh *et al.* (Adeoye *et al.*, 2020, Dendegh *et al.*, 2021). However, protein content observed in this study was greater than that reported in the two previous studies. This discrepancy could be

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attributed to the use of defatted soybean flour, which is higher in protein compared to regular soy flour (United State Agency for International Development (USAID), 2017). Adequate protein is essential for preschoolers to support their growth and development, as well as to prevent kwashiorkor. Low fat content in the improved flour might be attributed to the defatting of soybeans, suggesting that these products have a longer shelf life when packaged properly. Preschoolers also require sufficient fat as it serves as a source of energy, aids in the absorption of fat-soluble vitamins, and contributes to hormone production. To meet their RDA, preschoolers can enhance their meals made with these types of flour by mixing them with oil-rich soups.

Low fiber content of the improved flour can be attributed to the dehulling of soybeans. To enhance gastrointestinal health, it is recommended to consume porridge made from these types of flour alongside vegetable-rich soups. The ash content of a food material indicated its mineral richness, and this content increased with higher levels of soybean inclusion in the mixture. This finding is consistent with the research conducted by Shabo *et al.* (Shabo *et al.*, 2022). Carbohydrates are important sources of energy for children, and their availability supports protein utilization. Carbohydrate content of the flour decreased as the inclusion of soybean increased, which aligns with the findings of Dendegh et al. (Dendegh *et al.*, 2021), as soybeans contain more protein than carbohydrates. Energy content of the flour was higher than that reported by Igbua *et al*. (Igbua *et al.*, 2019) but lower than values stated by Shabo *et al*. (Shabo *et al.*, 2022). This variation could be attributed to differences in blending ratios and processing of food materials.

Preschoolers require a significant amount of energy for their metabolism, playing, and to prevent conditions such as marasmus. Therefore, their energy requirements can be supported by soups used with swallows made from these types of flour, as well as other food items consumed throughout the day.

The results of vitamin A analysis from this study align with findings by Asadu and Chwkwu (Asadu and Chwkwu, 2024); however, their reported values were lower due to a reduced inclusion quantity and different processing methods. Vitamin A is essential for good vision and a healthy immune system. In preschool children, vitamin B6 is crucial for proper brain development, the production of hemoglobin, and glucose metabolism. All flour samples analyzed were low in vitamin B6, and values obtained were lower than those reported by Torkuma *et al*. (Torkuma *et al.*, 2024). This difference might be attributed to the combination of animal and plant proteins used in their formulation. Folate (vitamin B9) is important for preschoolers, as it supports healthy red blood cells and DNA formation and contributes to a healthy nervous system. The folate content of the flour in this study was higher than that reported by Torkuma e*t al*. (Torkuma *et al.*, 2024), likely due to the presence of folate in *J. tanjorensis* leaves, which contain 2.52 mg of folate per 100 g on a dry basis (Iheanacho *et al.*, 2024). Vitamin B12 content in the flour was higher than the levels reported by Akinsola *et al*. (Akinsola *et al.*, 2017) and also met the daily RDA for preschool children. Vitamin B12 is essential for brain development, cognitive function, and neural myelination. It also works in conjunction with vitamin B9 to support red blood cell production. Generally, plants are not considered good sources of this vitamin; however, the material balancing used in this study helped the flour meet the RDA for preschoolers, making them a viable food choice for vegan children. Vitamin E is a crucial antioxidant that boosts the immune system, helping to protect against infections, inflammation, and oxidative stress. In this study, only the improved flour met the RDA of vitamin E for preschoolers. Vitamin E levels found in this research were higher than those reported by Nchung *et al.*, which may be due to the contribution of vitamin E from *J. tanjorensis* leaves used in this study (Nchung *et al.*, 2024).

pH values indicated that acidity decreased with an increasing substitution of soybean, consistent with the findings of Oklo *et al.*, suggesting the

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flour samples in this study were not acidic and could be suitable for products aimed at preschoolers with peptic ulcers (Oklo *et al.*, 2022). Bulk density of the traditional flour was also higher than that of the improved flour. This aligns with the findings of Asadu and Chwkwu (Asadu and Chwkwu, 2024), indicating that the improved flour will be more cost-effective for packaging and transportation. Furthermore, products made from improved flour will be easier for children to digest. The traditional *Luam-Nahan* flour exhibited the least WAC, suggesting that it will have greater shelf stability (Adesanmi *et al.*, 2020). The increased WAC observed with the substitution of soybeans at levels of 10-40% indicated that the improved flour may reduce shelf stability but offer greater utility in preparing sauces and baked goods (Ijarotimi *et al.*, 2022). However, traditional flour exhibited the lowest water solubility when exposed to high heat. Therefore, the higher solubility index of the improved flour suggested that it can produce a lump-free consistency that is easier for young children to digest (Anon *et al.*, 2021). Since traditional flour had the lowest swelling power, the improved flour was expected to be more effective for making sauces, soups, and baked goods, as it can create thicker and more viscous gruels or dough.

Changes in the sensory attributes of the *Luam-Nahan* prepared from improved flour align with the findings of Cai *et al*. and Shabo *et al*. (Cai *et al.*, 2021, Shabo *et al.*, 2022). Caregivers' preference for the traditional *luam-nahan* was consistent with the research conducted by Chemutai *et al* and Okoye and Ene (Chemutai *et al.*, 2024, Okoye and Ene, 2018), which may be attributed to their familiarity with the traditional version. Moreover, their preference for the sample with a composition of 44:44:10:2 among the improved flour supported the recommendations from previous studies (Aduke, 2017, Noah and Omoyeni, 2020), which suggest incorporating 10-15% soybean flour and less than 5% green vegetable flour, as recommended by Onoja *et al*. (Onoja *et al.*, 2014), for improved acceptability among mothers. Results indicated that consumer food acculturation is a gradual process. Preschoolers show a preference for improved *Luam-Nahan* with 10% soybean inclusion over the traditional version. This preference may be due to their familiarity with soybeans from other soybean-enriched food items they have consumed. It also suggested that children tend to favor only slight modifications in food for better acceptability.

This study has several strengths, including its utilization of locally available and nutrient-rich food materials in the development of nutritionally improved *Luam-Nahan* flour. It is a culturally acceptable food-based approach for sustainable malnutrition prevention. The incorporation of sensory evaluation, particularly among preschool children, provided valuable insights into targeted consumer preferences. Nevertheless, the study had some limitations. Result interpretations were based on laboratory food analysis, as the study did not investigate nutrient bioavailability of the improved flour. Defatting soyabean utilized in this study greatly increased the protein content of the improved flour and slightly increased moisture content, although it was still within the recommended limits. Hence, future studies are required on nutrient quality and bioavailability of the most acceptable improved flour with blend ratio of 44% QPM flour, 44% provitamin A flour, 10% soybean flour, and 2% *J. tanjorensis* leaves in animal models and human feeding experiment to evaluate its efficacy on the growth, development and health of preschool children in real world-settings. Moreover, future studies will be recommended to determine its shelf life under various storage conditions.

Conclusion

This study was designed in order to provide a culturally acceptable food based solution in the prevention and control of protein-energy malnutrition and micronutrient deficiencies among preschoolers who consume the traditional *Luam-Nahan* in LIMCs. It often contains low protein and micronutrients consequently leading to high rates of all forms of malnutrition and

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associated complications among them. The enhanced protein and vitamin content, along with functional properties of the improved *Luam-Nahan* porridge flour, can help meet nutritional needs of preschool children in this region. The consumption of the most acceptable nutritionally improved *Luam-Nahan* flour with blend ratio of 44% QPM flour, 44% provitamin-A flour, 10% soybean flour, and 2% *J. tanjorensis* leaves offering an optimal taste, alongside accompanying oil and vegetable rich soups is a recommended viable option for reducing high prevalence of protein-energy malnutrition and micronutrient deficiencies, particularly VAD in preschoolers as well as other consumers. The findings of this study, therefore, offers a highly promising culturally acceptable nutritional solution to address the critical problem of preschooler malnutrition in LIMCs.

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Authors' contributions

Daagema A, Ajayi K, Yetunde Talabi J, Dada IO, Chipili G and Adewuyi OO designed research; A. Daagema A, Ajayi K and Yetunde Talabi J conducted research; Daagema A, Ajayi K, Yetunde Talabi J, Dada IO, Chipili G and Adewuyi OO analyzed data; Daagema A, Ajayi K, Yetunde Talabi J, Dada IO, Chipili G and Adewuyi OO wrote the paper; Daagema A and Ajayi K, had primary responsibility for the final content. All authors have read and approved the final manuscript.

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