Development and Evaluation of the Physical and Nutritional Qualities of Extruded Millet-soybean Composite Flour and the Consumer Acceptability of its Instant Porridge

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Abstract

Malnutrition is a serious health concern in Tanzania because of its high frequency of disease and mortality. Cereal-based porridges are the most common complementary foods to children in the country. However, cereal proteins lack some essential amino acids necessary for children growth hence predisposing them to Protein Energy Malnutrition (PEM). The objective of this study was to develop and evaluate the physical and nutritional qualities of extruded millet-soybean composite flour and the consumer acceptability of its instant porridge as a food-based approach to reduce malnutrition in Tanzania. The millet and soybean were extruded and processed separately into flours which were then blended at 0, 10, 20, and 30% substitution rates for millet flour to make composite flours. The flours physical and chemical qualities as well as consumer acceptability of their porridge were evaluated using standard methods. The water absorption index (1.4 - 0.8 g/g), water solubility index (53.3 - 43.9%) and viscosity (95.10 - 5.61 dpas), of the flour slurries' and bulk density of the flours (0.82-0.62 g/ml) significantly (p<0.05) decreased as the amount of soybean flour increased in the formulations. However, all proximate composition parameters and iron in the composite flour formulations increased with the addition of soybean flour to millet flour, with the exception of carbohydrate. The 70% millet and 30% soybean composite porridge was the most acceptable formulation by consumers. Hence, development and consumption of millet-soybean composite flour and their porridge as a food-based strategy to combat children's malnutrition in the country is highly recommended

Keywords: Water, absorption, solubility, viscosity, bulky density, proximate, sensory.

Introduction

Malnutrition is regarded as one of the unwanted health conditions in the world because of its high frequency of disease and mortality (Ismail *et al.,* 2020). Globally in 2022, 149 million children were estimated to be stunted, 45 million were estimated to be wasted and 37 million were overweight. Furthermore, 1.9 billion adults are currently overweight or obese while 462 million are underweight (WHO, 2023). The most vulnerable populations are those with compromised immune systems, children, young people, women of reproductive age (18 and 49), pregnant women, and the elderly (Godoy *et al.,* 2017). Malnutrition is a serious threat to children under five years old and women who are of reproductive age in developing nations like Tanzania (Khamis *et al.,* 2020; Mtumwa *et al.,* 2016). According to a 2018 national study, 31.8 % of Tanzanian children are stunted, 3.6% are wasting, and 14% are underweight (URT, 2018). This disorder is caused by a complex array of circumstances, including poor breastfeeding practices and inadequate complementary feeding which is recommended to be started on children after six months of age (Kambale *et al.,* 2021: Abeshu *et al.,* 2016). This is due to the fact that breastfeeding is no longer adequate to meet a developing child's nutritional needs at this age (Headey *et al.,* 2018). As a result, eating a sufficiently diverse diet is essential.

However, in Tanzania, cereal-based foods are more common and are regularly served to children as a complementary meal. These meals, regrettably, are deficient in proteins and vital amino acids that are needed for a child's healthy growth and development, which predisposing them at risk for PEM.(Mollay *et al.,* 2021). Millet is one of the ingredients that is most commonly used in preparation of complementary foods for children of various age groups (Kinabo *et al.,* 2017). But millet lacks a number of vital amino acids, most notably lysine and threonine (Ahmed *et al.,* 2009). Consequently, children who consume millet as their only complementary food are at risk for PEM (Isingoma *et al.,* 2019). It has been reported that consuming foods that complement cereal and legumes offers a wealth of vital micro- and macronutrients that are critical for a child's nutrition (Shankar *et al.,* 2018).

Moreover, soybeans are particularly nutrient dense legumes that are commonly combined with cereals such as sorghum, millet, wheat, and maize to create complementary food diets (Tufa *et al.,* 2016), Furthermore, the utilization of extrusion cooking technique in the production of instant meals enhances the digestibility of the extruded products such as snacks and porridge flour (Coulibaly *et al.,* 2012). It has been shown that adding extruded soybean flour to millet flour significantly improves the flour's nutritional value and physical characteristics as well as the sensory properties and consumer acceptability of their prepared porridge (Filli *et al.,* 2010). This implies that properly prepared millet-soybean formulations could be a good way to combat childhood malnutrition across the country. The objective of this study was to develop and assess the physical and nutritional qualities of the extruded millet-soybean composite flour as well as the consumer acceptability of its instant porridge for children. Thus, serving as a food-based strategy to combat malnutrition in the country

Materials and Methods

Materials

Millet grains and soybeans, were purchased from the Chief Kingalu Municipal market in Morogoro, Tanzania. Food analytical grade chemicals and reagents were obtained from the Department of Food Science and Agro-processing Laboratory of the Sokoine University of Agriculture (SUA) where the analyses were conducted. Other ingredients and consumable materials for sensory analysis were obtained from respective shops in Morogoro.

Experimental designs

A completely randomized design (CRD) was used for the assessment of the physical and chemical composition of the products with the formulation being the main factor. The effects of this factor on the physical properties, proximate composition and mineral contents of the flour formulations were assessed and compared. The mathematical model is shown in Equation 1.

$$\gamma ij = \mu + \tau i + ij\varepsilon \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where μ is the overall (grand) mean, τi is the effect due to the ith treatment (formulation) and $ij\varepsilon$ is the error term.

Furthermore, a randomized complete block design (RCBD) was used to assess the consumer acceptability of the porridge samples with the panelists and formulation being the principal factors. The effects of these factors on consumer acceptability of porridge samples were assessed and compared. The mathematical model is shown in Equation 2.

$$\gamma ij = \mu + \tau i + \beta j + ij\varepsilon \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where μ is the overall (grand) mean, τi is the effect due to the ith treatment (formulation), βj is the effect due to the j^{th} block (panelists) and $ij\varepsilon$ is the error term.

Extrusion cooking of the millet and soybean

Preparation of samples

Millet grains were manually sorted to remove extraneous matter and damaged grains and washed with tap water in plastic basins to remove dust. The grains were then sun-dried for 10 hours until attained constant weight as described by Ndibalem (2011). On the other side, soybeans were cleaned, weighed, boiled in water for 40 minutes at 95°C, and allowed to cool to room temperature at 25°C for 10 minutes. The beans were dehulled by a cereal dehuller machine (RH-TK03, China) and the dehulled soybeans were washed thoroughly to separate them from the hulls and then sundried for 24 hours to 10% moisture content as described by Ndibalem (2011).

Extrusion Cooking

Extrusion cooking of millet and soybean was done separately at the Bio Innovate laboratory of the Department of Food Science and Agro-processing at SUA using a twin-screw extruder (Kneader Model EX 60, Chaoyuan Power Machinery. Co. Ltd, China). The feed mixture was metered into the extruder by a twin-screw volumetric feeder equipped with it. The extrusion process of soybean corresponded to that of millet. The process was carried out at the main motor at an initial speed of 33.70 rpm and feeder speed of 7.50 rpm, with a corresponding temperature of 130°C in zone I and 94°C in zone II. The final feeder speed was set at 8.20 rpm and a temperature of 136°C in Zone I and 110°C in Zone II. The extruded samples were then collected after the extruder system parameter reached a steady-state condition and left to cool at room temperature (25°C.) After extrusion, the extrudates were allowed to dry at room temperature and milled into flour by the hammer milling machines (9FQ500 - 40, China) into a sieve size of 1 mm. The extruded flour was packaged in polyethylene packets and kept at room temperature before further analyses.

Flour formulations

Composite flours were prepared by blending millet flour with soybean flour at 0, 10, 20, and 30% levels of millet flour substitution (Table 1). The composite flours were packed in small plastic bags in triplicates before physical and chemical analyses and porridge preparation for sensory analysis

Table 1: Formulation of millet soybean composite flours

Formulation	Flour proportion (%)	
	Millet	Soybean
Control whole millet (CWM_100%)	100	0
Millet-Soybean (MSB_1 (90%))	90	10
Millet-Soybean (MSB_2 (80%))	80	20
Millet-Soybean (MSB_1 (70%))	70	30

Porridge preparation for consumer acceptability

Porridge samples were prepared using the formulated composite flours, with 50 g of flour added to 350 ml of boiling water at 100°C. The mixture was continuously mixed until a thick, uniform mixture was obtained (instant porridge). The porridge was stored in an oven that was set to 50°C for 30 minutes in order to maintain its heat until the consumers' acceptability test.

Physical properties analyses

Determination of the Water Solubility Index (WSI) and Water Absorption Index (WAI) of the composite flour slurry

Water absorption index (WAI) and solubility index (WSI) were determined according to procedures described by Stojceska *et al.* (2008) and Yagci and Gogus (2008). One gram (1 g) of each sample was mixed with 10 ml of water in a separate centrifuge tube at 25°C and gently shaken by the shaker machine for about 30 minutes to attain a uniform mixture. The mixture was centrifuged for 10 minutes at 4000 rpm, and the supernatant was then decanted into an evaporating dish with a known weight before being oven-dried for sixteen hours. The dried components were weighed to obtain the mass of the dry solid supernatant and the WAI and WSI were calculated using the formula shown in Equations 4 and 5 respectively.

$$WAI\left(\frac{g}{g}\right) = \frac{(Weight\ of\ wet\ gel - Dry\ weight\ extrudate)}{A\ dry\ weight\ of\ extrudate} \quad ..(4)$$

$$WSI(\%) \frac{Weight\ of\ \ Dry\ solid\ in\ the\ supernatant}{The\ dry\ weight\ of\ Extrudate} \quad ...(5)$$

Determination of viscosity of the flour slurry.

The viscosity of the flour slurry was determined using a viscometer as described by Treche (2001). About 1 g of each sample was mixed with 10 ml of hot water at 50°C in a separate centrifuge tube and gently shaken by the shaker machine for about 30 minutes to attain a uniform mixture. The viscosity of the slurry of each formulation was separately analyzed in triplicate using a viscometer (Viscotech MYR VR 3000, German). The results were expressed as Deci paschal per second (dPas).

Determination of the bulk density of the flour

The bulk densities of the flour formulations were determined according to the procedure described by Stojceska *et al.* (2008). The bulk density was calculated by taking the ratio of the sample weight in the cylinder to its volume using a formula shown in Equation 3.

$$\text{Bulk density}\left(\frac{g}{cm^3}\right) = \frac{\text{the weight of the cylinder and sample weight of the empty cylinder }(g)}{\text{The volume occupied to fill the mark of a cylinder }(cm^3)} \quad .(3)$$

Chemical analyses

Proximate analysis of composite flour formulations

Proximate compositions of the composite flours were determined by using the Association of Official Analytical Chemists' standard procedures (AOAC, 2005). Moisture content was determined by oven drying (Method 925.10), fat by Soxhlet extraction (Method 2003.05), ash by combustion (Method 923.03), crude fibre by dilute acid, and alkali hydrolysis (Method 978.0), and proteins by micro Kjeldahl method (Method 960.52). A conversion factor of N=6.02 was used for the calculation of protein content. The carbohydrate content was determined by different methods (AOAC, 2005). Each proximate parameter was analyzed in triplicate and computations were based on a dry weight basis.

Determination of minerals contents of composite flour formulations

Ash was used for mineral content analysis using AOAC standard methods (2005). Zinc and iron contents were analyzed by Atomic Absorption Spectrometer (AAS) (Unicam 919, Pye Unicam, England). The ash was dissolved in 20 ml of 1 N HCl and heated for 5 minutes at 80-90°C. Each sample was analyzed in triplicate and quantification was accomplished by comparison with a standard curve drawn using a standard solution of known concentrations at 0.5, 1.00, 1.5, and 2.5 ppm. The mineral content was obtained using the formula shown in Equation 6.

$$Mineral\ content\ \left(\frac{mg}{100g}\right) = \frac{R \times 100mil \times DF}{S \times 1000} \ldots (6)$$

Where R is the reading value (in ppm), 1000 is the conversion factor to mg/100 g, DF is a Dilution Factor and S is a sample weight (g).

Consumer acceptability of the porridge formulations

The consumer acceptability of the different instant porridge formulations was conducted at the Department of Food Science and Agro-processing laboratory at SUA by 110 untrained adult panelists. A nine-point hedonic scale (whereby 1 = dislike extremely and 9 = like extremely) was used as described by Civille and Carr (2015). Fifty (50 mL) of each porridge formulation coded with 3-digit random numbers were served in a cup to each consumer at 45 - 50°C in a randomized order. The consumers were asked to assess the samples and express their degree of liking for appearance, colour, aroma and viscosity attributes, and overall acceptability. Testing was completed in one session considering all good sensory practices such as testing environment, sample coding, and serving conditions such as constant temperature maintenance using thermo flasks, and testing protocol (Civille and Carr, 2015).

Statistical data analyses

The data were analyzed by R Commander Software (R Core Team, version 3.0.0 Vienna Austria) for one-way and two-way analysis of Variance (ANOVA). One-way ANOVA was used to determine significant variations in physical properties and proximate and mineral compositions between extruded sample formulations. Two-way analysis of variance (ANOVA) was used to determine significant variations in consumer acceptability of the sensory attributes and overall liking between the formulations. The means were separated by Tukey's Honestly Significant Difference (THSD) at $p<0.05$. Principal component analysis (PCA) was performed using LatentiX Software (Latentix, Frederiksberg, Denmark, 2015) to determine systematic variations in the proximate composition and physical and chemical properties between the flour formulations.

Results and Discussion.

Physical properties of composite flour formulations

Table 2 shows the physical properties of the formulations. Control whole millet formulation had significantly ($p<0.05$) highest values of all physical properties which decreased progressively with increasing levels of soybean flour proportions in the formulations. The reduction was more pronounced in 70% millet and 30% soybean flour formulation (MSB_3).

Table 2: Physical properties of the composite flour formulations

Samples	Water absorption index (g/g)	Water solubility index (%)	Viscosity (dpas) (50 °C)	Bulk density (g/ml)
CWM (100:00)	1.4 ± 0.03a	53.3 ± 0.09a	95.10 ± 0.02a	0.82 ± 0.03a
MSB_1 (90:10)	1.3 ± 0.07b	48.2 ± 0.09b	22.94 ± 0.05b	0.78 ± 0.04b
MSB_2 (80:20)	1.3 ± 0.04b	47.3 ± 0.10b	8.82 ± 0.07c	0.75 ± 0.2b
MSB_3 (70:30)	0.8 ± 0.09c	43.9 ± 0.03c	5.61 ± 0.01d	0.62 ± 0.11c

Values are expressed as arithmetic mean and standard deviation (n = 3). Values with different superscript letters along the column are significantly different at p < 0.05. CWM is a control whole millet and MSB is a millet-soybean sample

Water absorption index (WAI) and water solubility index (WSI)

Water absorption index (WAI)

Water Absorption Index (WAI) and Water Solubility Index (WSI) are related to the functional properties of starch. The WAI is an indicator of the ability of flour to absorb water and swell for desirable consistency in the food system, which improves yield and consistency, and gives body to the food (Choi *et al.,* 2012). It provides information on how easily the starch absorbs water (Mahenge, 2018). The observed higher WAI in the whole millet flour slurry than blend flours could be due to their high starch contents which gelatinized more during extrusion cooking attributed to barrel temperature (Altan *et al.,* 2009).

The addition of soybean lowered the starch content of the flour formulation and increased its oil content thereby interfering with the water uptake mechanism, resulting in a substantial decrease of WAI (Filli *et al.,* 2010). Similarly, low WAI values due to reduced starch contents in the flour blends have been reported earlier for the millet-legume blend by Chakraborty *et al.* (2011). The low WAI of flour in the blend is very important for ensuring the shelf-life stability of the product. Flour with a low WAI minimizes the ideal conditions for microbe growth, allowing the product to have longer shelf stability while maintaining its physical and nutritional properties (Osundahunsi and Aworh, 2002).

Water solubility index (WSI)

The WSI is used to indicate starch degradation, and thus it determines the amount of free polysaccharide or polysaccharide released from the granule with the addition of excess water (Osundahunsi *et al.,* 2003). The observed higher WSI in the control whole millet slurry could be due to their high starch content, allowing for more dextrinization and depolymerization of starch at extrusion temperatures (Olu *et al.,* 2012). This resulted in a decrease in the molecular weight of amylose and amylopectin, which increased the slurry's solubility. However, this observation is contrary to the study done by Byaruhanga *et al.* (2014) and Mahenge (2018), who respectively observed the increase in WSI with the increase in soybean and cowpeas flours in sorghum flour. This variation could be related to the fact that WSI is explained not just by the starch concentration of the flour, but also by water-soluble components like proteins found in soybeans (Filli *et al.,* 2010). The higher the protein content in the formulation the higher the WSI as previously reported in cowpea flour with relatively higher protein than sorghum flour (Pelembe *et al.,* 2002). The reduction of WSI of the composite flour with the increase in soybean flour up to 30% implies that the composite flour was still mostly composed of starch aggregates, and had comparatively high lipid and soybean protein content (Pelembe *et al.,* 2002), hence its instant porridge could still be nutritionally appealing for children.

The Viscosity of the flours slurry

The observed decrease in slurry viscosity as the percentage of soybean flour in the formulation' increases could potentially be attributed to the high oil content and loosen structure of the starch polymers from the soybean flour. According to Mahenge (2018), the low viscosity of the instant porridge from extruded flour is nutritionally beneficial for young infants as it aids in easy mastication and swallowing. The comparatively lower viscosity of the MSB_3 formulation falls within the recommended range of less 5 dpas for making porridge for children as suggested by Gardner *et al.* (2002). According to Gardner *et al.* (2002), porridge with this viscosity level is better for infants because it makes it easier for them to ingest more food, more easily and increases the porridges nutrient density. This suggests that the creation and consumption of porridge and composite flour made of 70% millet and 30% soybeans may be a promising food-based strategy to reduce child malnutrition in the country and should be promoted.

The Bulk Density

The bulk density (BD) is a measure of the heaviness of the flour (Nicole *et al.,* 2010) and is directly related to the structure of the starch polymer. The loose structure of the starch polymer corresponds to a reduction in flour BD (Olu *et al.,* 2012). The observed higher BD in the control whole millet formulation than in composite flours could be due to the relatively higher starch polymer in millet than in soybean (Coulibaly *et al.,* 2012). The increase in soybean flour in the formulations resulted in significant reduction of the starch polymer and the BD. Similar effects of soybean flour in the reduction of BD of the composite flour was also observed in corn-soybean soup (Mohajan *et al.* (2018). Furthermore, the higher BD in the porridge flour indicates more starch than protein and lipids. Hence dilution of millet flour with other low starch flour reduces the BD and enhances the nutritional qualities of the final flour. Similarly, Nicole *et al.* (2010) observed that, flour with low BD makes it ideal for making complementary foods for young children. A loose BD not only promotes easy food digestion but also increases nutrient diversity and calorie density per feed, giving complementary foods an added advantage, especially for children with immature digestive systems (Osundahunsi and Aworh, 2002).

Proximate and mineral compositions

The proximate and mineral compositions of the flour formulations are shown in Table 3. The control whole millet formulation had significantly ($p<0.05$) lower values for all proximate parameters except for carbohydrate value. The values increased progressively with the increased levels of soybean proportion in the formulations (Table 3).

Furthermore, mineral contents differed significantly ($p < 0.05$) between the formulations with the control whole millet formulation sample having higher zinc and lower iron values than the composite formulations. These values decreased and increased respectively with increasing levels of soybean in the formulations (Table 3).

The findings have demonstrated that incorporation of soybean flour into the millet flour enhances the nutritional quality of the composite flour as similarly reported by Taghdir *et al.* (2017). However, Nkama and Bulus (2006), reported higher values of proximate parameters than those reported in this study. These discrepancies may be related to changes in the optimal conditions for the extrusion cooking process, primarily feed moisture, barrel temperature, and screw speed (Singh *et al.,* 2019). The high nutritional values of the millet soybean composite flour suggest its suitability for the preparation of complementary food for children to combat malnutrition in developing countries like Tanzania. Consumption of high-protein food sources that meet the daily Recommended Dietary Allowance (RDA) is crucial to combat PEM in children (Bandyopadhyay *et al.,* 2020).

Table 3: Proximate and mineral composition of the extruded millet-soybean flour

Proximate composition						**Parameter**
Formulation	Lipid (g/100 g DM)	Protein (g/100 g DM)	Ash (g/100 g DM)	Crude fibre (g/100 g DM)	CHO (g/100g DM)	Energy (Kcal)
CWM (100:00)	1.5 ± 0.08a	9.5 ± 0.07a	3.3 ± 0.09a	1.9 ± 0.08a	83.8 ± 0.09a	386.7 ± 0.01a
MSB_1 (90:10)	2.5 ± 0.06b	13.6 ± 0.05b	3.5 ± 0.10ab	2.2 ± 0.06b	78.2 ± 0.07b	389.7 ± 0.03b
MSB_2 (80:20)	3.8 ± 0.22c	15.7 ± 0.04c	3.6 ± 0.10bc	2.6 ± 0.44c	73.9 ± 0.05c	392.6 ± 0.05c
MSB_3 (70:30)	5.7 ± 0.03d	17.6 ± 0.02d	3.8 ± 0.11c	2.9 ± 0.25d	70.3 ± 0.03d	402.9 ± 0.07d
Mineral composition						
Formulation					**Zinc (ppm)**	**Iron (ppm)**
CWM (100:00)					10.2 ± 0.22a	66.6 ± 0.23a
MSB_1 (90:10)					9.8 ± 0.21a	67.2 ± 0.23a
MSB_2 (80:20)					7.1 ± 0.11b	71.3 ± 0.10bc
MSB_3 (70:30)					7.0 ± 0.10b	73.0 ± 0.09c

Values are expressed as arithmetic mean and standard deviation (n = 3). Values with different superscript letters along the column are significantly different at p < 0.05. CWM is a control whole millet, MSB is millet soybean samples and CHO is a carbohydrate.

Nkama and Bulus (2006) noted a comparable rise in protein content with increasing amounts of soybean flour in formulations. In this study, adding soybean flour at 20 and 30% in place of millet flour significantly raised the protein level from 18.0% to 21.1%. Further analysis of the results, revealed that consuming 500 ml of porridge made with 70% millet and 30% soybean composite flour suffices to meet the RDA for the protein of 1.2 grams per kilogram body weight for children (Lonnie *et al.,* 2018). Furthermore, the significant increase in other proximate parameters except for carbohydrates suggests that substituting millet flour with different levels of soybean enriches the nutritional quality of the composite flour including micro and macronutrients. This also shows their suitability for alleviating malnutrition in children in the country.

Sufficient consumption of iron and zinc through diet is essential for both immune system strengthening and growth and development (Adetola *et al.,* 2020). The observed increase in iron content in the composite formulations could be linked to the high iron concentration in soybeans. This could also be linked to to improvement of the bio-accessibility of the iron-bound in the phytate of most legumes including dry beans and soybean by extrusion cooking temperature (Mezgebo *et al.,* 2018). A similar increase in iron content due to the increasing proportion of soybean in the formulation was previously reported in soy-mushroom formulations (Muoki *et al.,* 2015). Therefore, the inclusion of cereal-legume complementary foods rich in zinc and iron in right proportions in the normal diet of children may serve as a food-based strategy to reduce malnutrition and its related consequences.

Multivariate approach

The systematic variations between millet-soybean porridge flour samples with their associated proximate composition, mineral contents, and physical properties are presented in a multivariate PCA plot (Fig. 1). PC 1 accounts for 91.1% of variability separating control and 10% of samples associated with high carbohydrate and zinc loadings on one side and 20 and 30% of samples associated with proximate parameters and iron on the other side. PC 2 accounts for 5.8% and it separates the control sample and 10% of samples on physical properties as well as 20 and 30% on proximate

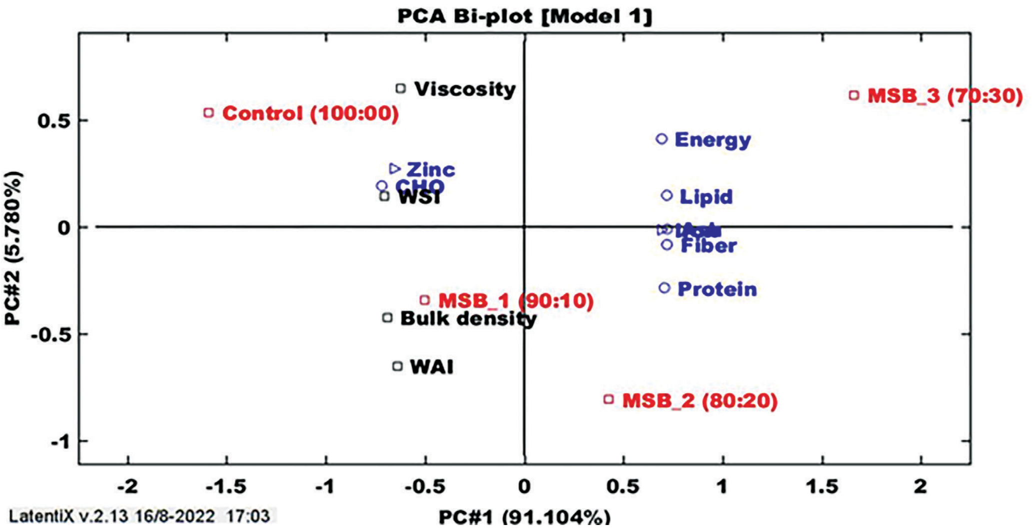

Figure 1: PCA biplot showing systematic variation between millet-soybean porridge flour samples with their associated proximate composition and physical and chemical properties. CHO is carbohydrate

composition parameters. Generally, the plot shows three main groups of formulations with their associated nutrients and physical properties.

Consumer acceptability of the composite porridge formulations.

There were significant (p<0.05) differences in mean hedonic scores between the formulations (Fig. 2). The control whole millet formulation had significantly lower hedonic values for all sensory attributes and overall acceptability which increased progressively with the increasing level of soybean in the formulations.

The consumer acceptability test is critical in the development of food products because

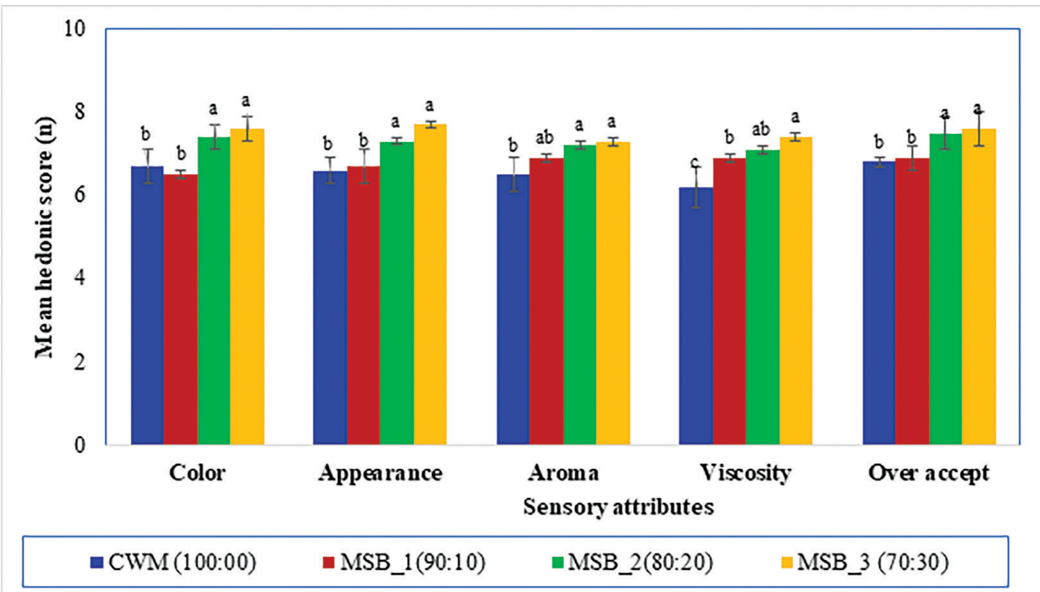

Figure 2: Mean hedonic scores of porridge samples (n= 110). Values with different superscript letters are significantly different at p<0.05. CWM is a control whole millet and MSB is a millet-soybean sample

it reveals how customers will prefer or accept a product based on its sensory characteristics (Lawless and Heymann, 2010). The increase of soybean flour proportion in the blend is highly associated with the increase in the acceptability of colour, aroma, and viscosity attributes of the instant porridge (Muoki *et al.,* 2015). Similarly, the addition of soybean in the formulations enhanced sensory properties with increased overall consumer acceptability of the instant porridge formulations. A similar increase in the acceptability of colour, viscosity, aroma, and the overall acceptability of the extruded millet-soybean porridge with the increase in soybean flour proportion has also been reported in Nigeria (Minweyelet *et al.,* 2021).

Conclusion

Given the findings of this study, the incorporation of soybean flour into a millet flour lowers the composite flour slurry's water absorption index, water solubility index and viscosity. It also lowers the bulk density of the composite flour formulations compared to the control whole millet formulation. Furthermore, all proximate composition parameters and iron in the composite flour formulations increased with the addition of soybean flour to millet flour, with the exception of carbohydrate. The 70% millet and 30 % soybean composite porridge was the most acceptable formulation by consumers. Hence, development and consumption of millet-soybean composite flour and their porridge as a food-based strategy to combat children's malnutrition in the country is highly recommended.

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Conflict of Interest: None

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