Functional and Sensory Quality of Complementary food blended with Moringa Leaf Powder.

2.0 Abstract

Functional and Sensory Quality of Complementary porridge made from Moringa Leaf Powder blended with Pearl millet, Orange-Fleshed Sweet Potato, Dates was evaluated using standard methods. The Pearl millet grain flour, Moringa leaf powder and dates were blended in ratios of 90:2.5:7.5 [PmMD1], 95:2.5:2.5 [PmMD2], 88:3:9 [PmMD3] respectively. Also, Pearl millet grain flour, Moringa leaf powder and Orange fleshed sweet potato were blended in ratios of 95.5:2:2.5 [PmMP1], 88:2:10 [PmMP2], 95:2.5:2.5 [PmMP3], respectively. The ratios were calculated based on Recommended Daily Allowances (RDA) for children aged 1-2 years. Control sample was blended with Pearl millet, Dates and Orange fleshed sweet potato in a ratio of 50:15:35 [PmDP], respectively. A significant difference ($p<0.05$) in bulk density and viscosity were observed due to the difference in amounts of Orange fleshed sweet potato and Dates. No significant difference ($p>0.05$) in water absorption capacity was observed. Sensory evaluation showed significant difference ($p<0.05$) between all samples and in all sensory parameters namely aroma, taste, color and overall acceptability. The sample PmDP was the most accepted in terms of color whereas PmMP2 was the most accepted in terms of aroma, taste and overall acceptability. Quantitative descriptive analysis was conducted to determine the intensity of color, aroma, sweetness, thickness and grittiness among the samples. No significant difference ($p>0.05$) in the intensity of color, aroma, thickness and grittiness. There was a significant difference in the intensity of sweetness among the samples ($p<0.05$) and the mean values ranged from 4.2-1.9. The control sample [PmDP] had the highest value in sweetness intensity as it contained Orange fleshed sweet potato and Dates which are both of a sweet nature. A PCA biplot was drawn to indicate the association between the samples and the attributes. All ingredients used in this study had a different contribution in the functional quality of the porridge together with the sensory quality.

2.1 Introduction

Complementary foods refer to the introduction of solid foods to children aged from 6 months and older in order to meet their daily nutritional needs [1]. This transition occurs because breastfeeding alone becomes insufficient in providing all the necessary nutrients for the child. According to the World Health Organization [2], the introduction of complementary food should be timely, meaning it should be provided when a child's energy requirements exceed what breastfeeding alone can offer. Additionally, the food should be adequate, ensuring it provides sufficient energy, protein, and micronutrients for the child's growth. Safety is another important aspect, requiring that the food is stored and prepared hygienically to ensure the child's well-being. Lastly, proper feeding practices involve offering food based on the child's signs of hunger and fullness.

Composite flours are composed of a combination of cereals (such as millet, wheat, and maize), starchy roots and tubers (such as yam, cassava, and sweet potato), as well as protein-rich foods (such as soy and peanuts). It is important to note that no single cereal or legume can independently provide all the necessary nutrients to meet a child's requirements. By combining ingredients from different food groups, overall nutrition can be improved. Current understanding in the field of children's nutrition allows for the mixing or fortification of one food substance with another, resulting in a blend that possesses both nutritional quality and consumer acceptance [3].

Pearl millet (*Pennisetum glaucum*) is a highly nutritious grain crop known for its ability to withstand drought and resilience. It serves as an excellent source of carbohydrates, offering a low glycemic index. Furthermore, pearl millet is rich in dietary fiber and essential minerals, including iron, magnesium, and potassium, as well as a variety of B vitamins [4]. In Tanzania, pearl millet is commonly used as a key ingredient in the preparation of porridge for children [5].

Moringa oleifera, a highly nutritious tree, has gained recognition as a valuable reservoir of essential nutrients. It is considered as a very good supplement because of its high protein value and that encompasses all the necessary amino acids. It is also known as the miracle tree because of its diversified beneficial features, e.g., rich source of iron, 10 times more vitamins than carrots, 7 times more vitamin C than oranges, 17 times more calcium than milk, and 15 times more potassium than bananas [6]. Moringa leaves are also an excellent source of dietary fiber, phytochemicals, and antioxidants. Due to their nutrient density, they are employed to combat malnutrition and its associated effects [7].

Dates are the fruit produced by the date palm tree, *Phoenix dactylifera*. These fruits are naturally sweet and often consumed as a snack or added to different dishes to enhance their taste. Dates offer a rich source of both soluble and insoluble fiber, as well as essential minerals such as copper and potassium [8]. Moreover, they possess anti-inflammatory and anticancer properties. As a healthier option compared to refined sugars, dates are frequently used as natural sweeteners in food preparations.

Orange-fleshed sweet potato (*Ipomoea batatas*) is a type of sweet potato with vibrant and distinct orange-colored flesh. The captivating color is a result of a substantial content of *Beta-carotene*, which is crucial for promoting eye health, supporting immune function, and facilitating overall growth and development. These sweet potatoes serve as a valuable source of carbohydrates and dietary fiber. Additionally, they provide essential B vitamins and minerals, such as manganese [9]

Porridge is a common food given to infants. Pearl millet, Orange-fleshed sweet potato, Dates, and Moringa leaves can be used in preparation of porridge. Functional characteristics of porridge encompass its visual appearance, texture, consistency, viscosity, and mouthfeel, all of which contribute to the initial impression before consumption. These aspects play a significant role in determining the overall acceptance of the porridge. Factors such as cooking time, ingredients selection, and the ratio of water to ingredients directly impact the functional quality of the porridge [10]. In this particular study, a blend of Pearl millet, Orange-fleshed sweet potato, Dates, and Moringa leaves were used to produce complimentary flour for preparing porridge. Subsequently, sensory and functional quality tests were conducted on the resulting blends.

2.2 Materials and Methods

Samples

Pearl millet and Orange fleshed sweet potato were obtained from Mawenzi market, whereas Moringa leaves were obtained from Frida homestead, Morogoro Tanzania. Dry dates were obtained from Kilombero market, in Arusha Tanzania.

Preparation of Moringa leaf powder (MLP).

The fresh Moringa leaves from the farm were sorted and the young and fresh leaves were selected. Damaged and diseased leaves were discarded. The leaves were washed with clean water and soaked in 1% NaCl for 5 minutes solution to kill microbes. The excess water was drained and leaves were spread out on racks for 20 minutes before being shade dried at room temperature for 4 days. A high-speed multifunctional crusher model 750A was used to grind the leaves to powder. A 500µm sieve was used to obtain a fine powder [11], [12].

Preparation of Orange-Fleshed Sweet Potato (OFSP) Flour.

Sweet potatoes were washed, peeled, and chopped into 3mm thick slices. The slices were oven dried at 50˚ C overnight and later milled using a high-speed multifunctional crusher model 750A. A 500µm sieve was used to obtain a fine powder [13].

Germination and Preparation of Pearl millet (Pm)

Pearl millet was sorted to remove extraneous matter and then washed to remove dust and mud. The sorted and cleaned millet was soaked in a 5 L bucket containing cold water for 10 h at room temperature. Water was drained from the millet grains and spread individually on wet muslin cloth where water was sprinkled at 6h break to stimulate the germination process. The millet grains germinated for 48 hours. The germinated millet was oven dried at 60˚C for 10 h and was then ground using a hammer mill into flour. A 500µm was used to sieve germinated flour [14]. All the flour samples were kept in air-tight polyethylene bags and kept in a freezer at -10˚C.

Preparation of Date Powder

Dried dates from the market were washed with clean water to remove dust. Inner seeds were also removed and the dates were kept in the oven for 12 hours at 60^0C. They were then left to dry for one hour. A high-speed multifunctional crusher model 750A was used to crush the dates so as to obtain a powder that was then sieved using a 500 µm [8]

Sample Formulation and Composition

The formulation and preparation of complementary food mix made from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf are shown in Table 1 and Figure 1, respectively. Combination of food sample ratios were calculated into different formulations to meet the

FAO/WHO/UNICEF (1985) requirement for micronutrients for young children and infants. From this, seven samples (including the control sample) were formulated as indicated in Table 1.

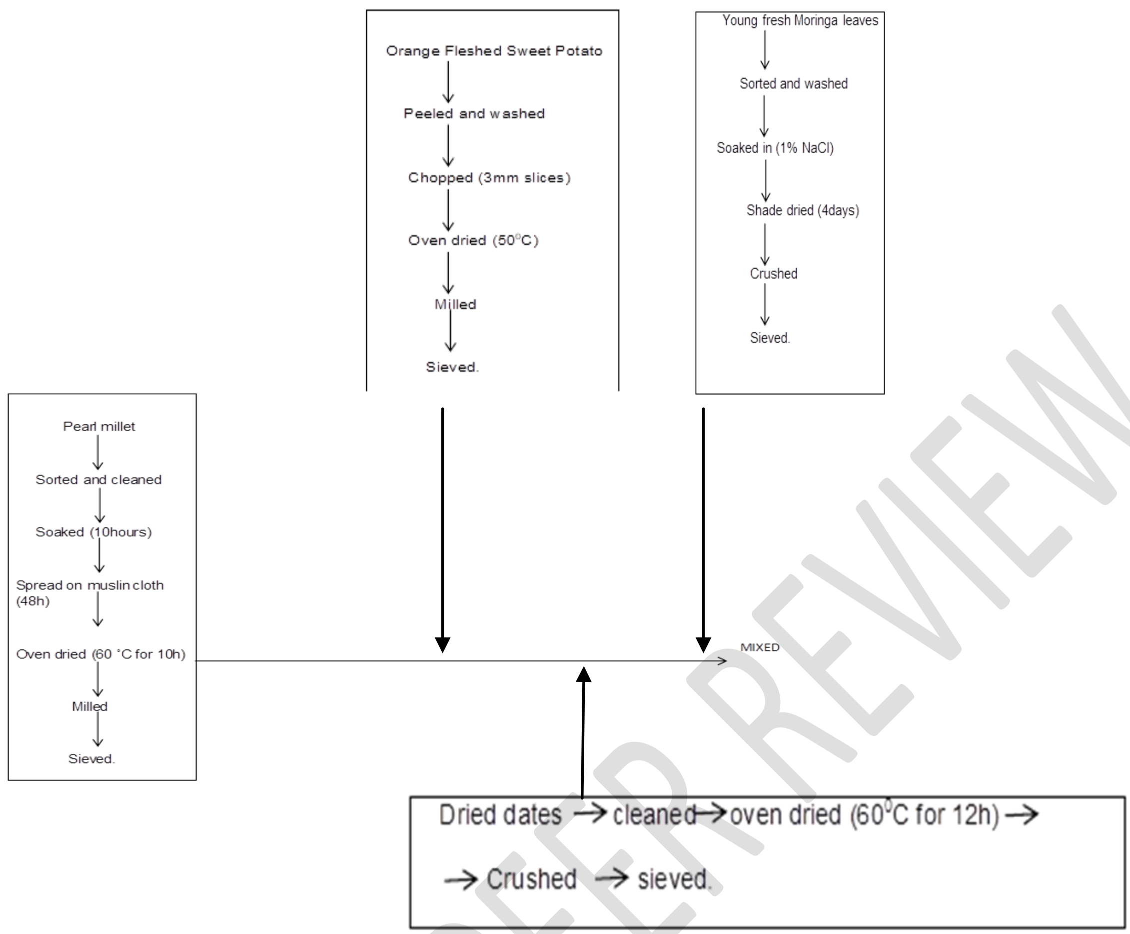
Table 1: Composition of complemented food from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf (g/100 g)

Ingredients	Formulation Name	Ratios
Pearl Millet+ Moringa leaf powder+ Dates	PmMD1	90:2.5:7.5
	PmMD2	95:2.5:2.5
	PmMD3	88:3:9
Pearl Millet+ Moringa leaf powder+ Orange-fleshed sweet potato	PmMP1	95.5:2:2.5
	PmMP2	88:2:10
	PmMP3	95:2.5:2.5
Pearl Millet+ Dates + Orange- fleshed sweet potato (Control sample)	PmDP	50:15:35

Where Pm = Pearl Millet, M= Moringa Leaf, D= Dates, P= Orange fleshed sweet potatoes

Samples from Table 1 were prepared using flour and water in a proportion of 350g to 1000L they were cooked at medium heat for 15 minutes. The cooked porridge samples were kept in a thermos- flask ready for laboratory analysis and sensory evaluation [12].

Fig.1. Flowchart for the preparation of complementary food powder



2.3 Analyses

2.3.1 Bulk density

The method used for the determination of the Bulk density (BD) of the samples was described by [15]. The bulk density of the samples was calculated by taking the ratio of sample weight in a cylinder to its volume.

Bulk Density was calculated using the formula:

$$BD\ (g/\text{ml}) = \frac{Weight\ of\ sample}{Volume\ of\ sample}$$

2.3.2 Viscosity

HAACE Viscotester 2plus (Thermo-electron company, Karlsruhe, Germany) was used to determine the viscosity of the porridge samples. Samples of 100 mL of each in duplicate were prepared for the test and porridge samples were used for the determination of viscosity.

2.3.3 Water Absorption Capacity (WAC)

Water Absorption Capacity was determined by using the method for cereals described by [16]. Porridge flour samples were sieved into fine flour with a particle size of 500 µm. One gram of each sample was suspended in 10 mL of distilled water at room temperature (approximately 28 ^{o}C) and gently stirred for 30 min then centrifuged at 3000 rpm for 10 min. The supernatant was decanted into an evaporation dish of known weight. The water absorption index was the weight of gel obtained after the removal of the supernatant per unit weight of original dry solids. The supernatant was then dried in an oven at 105^{o}C overnight, and the weight of the dried supernatant was then recorded.

The water absorption index was calculated using the following formulae:

$$WAI(g/g) = \frac{weight\ of\ wet\ gel}{weight\ of\ the\ sample}$$

2.3.4 Sensory evaluation

Sensory evaluation was conducted was by quantitative descriptive test (QDA) and consumer tests [17]..

2.3.5 Quantitative descriptive analysis

QDA was conducted at the Department of Food Science and Technology by ten trained sensory panelists, comprising 5 males and 5 females with ages ranging from 21 to 28 years according to the method described in [18]. Panelists were trained to develop sensory descriptors and the definition of the sensory attributes. They developed a test vocabulary describing differences between samples and agreed upon 5 descriptors for color, aroma, sweetness, thickness, and grittiness attributes (Table 2). An unstructured line scale was used for rating the intensity of an attribute whereas a 5-point hedonic scale was used. The left side of the scale corresponded to the lowest intensity of each attribute (value 1) and the right side corresponded to the highest intensity (value 5).

Table 2: **Attributes, references, and anchors developed in quantitative descriptive analysis panel training**

Attribute	Definition	Reference	Anchors

Color	Color Intensity	Brownish	Low to High
Aroma	Aromatic	Cooked porridge aroma	Low to High
Sweetness	Sweetness Intensity	Sweetness associated with 1% sucrose solution	Not sweet to very sweet
Thickness	Porridge Viscosity	Thickness associated with honey viscosity	Not viscous to very viscous
Grittiness	Particle present in porridge	Presence of chewable particles in the porridge	Low to High

2.3.6 Consumer test

Consumer test was carried out at SUA maternity clinic, Mazimbu Hospital, Morogoro in which 30 semi-trained panelists who were mothers, 40% aged between 16-26 and 60% aged between 26-50 years old were used. A 7- point hedonic scale was used (where 1 = dislike very much and 7 = like very much) as described by [18]. Panelists were instructed to rate color, aroma, flavor and overall acceptability indicating their degree of liking or disliking by indicating the number provided according to their preference.

In both tests, the samples to be tested were coded with 3-digit random numbers and served to each panelist in clean white disposable cup. A bottle of drinking water was provided for the judges to rinse their mouths after each test.

2.3.7 Statistical analysis

Statistical data analysis was performed by using SPSS (Statistical package for the social Sciences Version 26.0. SPSS Inc., Chicago, IL, USA), using the one-way analysis of variance (one way ANOVA) and post hoc Turkey's Honestly Significant Difference (HSD) test at a significance level $p < 0.05$. All the data were reported using mean values of determinations ± standard deviation. Principle component analysis (PCA) was done by R software (R Core Team) to assess the association between sample and attributes.

3.0 Results and Discussion

Functional properties of the porridge samples

Bulk Density

Bulk density is a measure of the heaviness of flour and the porosity of a product that is often affected by the particle size and density of the flour [19]. It is important for determining packaging requirements on the volume of the material, cost together with the choice of the raw material. It is also useful in material handling together with its application in wet processing in the food industry[20] .The results of functional properties of the formulated porridge samples are shown in Table 3 and indicates a significant difference in Bulk density at ($p<0.05$) among the samples. The sample PmMP2 had the bulk density (1.43) followed by the control sample PmDP (1.41). In both “PmMD” and “PmMP” groups bulk density increased as the concentrations of MLP, OFSP, and dates increased. Low bulk density was probably influenced by the nature of the starch polymers which had a loose structure [21]. The lowest values were observed in the samples that contained the least amounts of dates. This trend shows the addition of other ingredients after reduction of pearl millet, increased the bulk density.

Table 3: Functional properties of the porridge samples

Sample	Bulk density	WAC(g/g)	Viscosity (dpas)
PmDP	1.41 ± 0.14^{b}	8.65 ± 0.08^{c}	2.2 ± 0.14^{h}
PmMD1	0.60 ± 0.01^{a}	8.48 ± 0.20^{c}	0.72 ± 0.00^{de}
PmMD2	0.56 ± 0.01^{a}	8.53 ± 0.03^{c}	0.59 ± 0.00^{d}
PmMD3	1.41 ± 0.05^{b}	8.30 ± 0.17^{c}	0.75 ± 0.00^{def}
PmMP1	1.30 ± 0.04^{b}	8.60 ± 0.30^{c}	0.85 ± 0.00^{ef}
PmMP2	1.43 ± 0.04^{b}	8.69 ± 0.24^{c}	1.81 ± 0.00^{g}
PmMP3	1.37 ± 0.06^{b}	8.64 ± 0.36^{c}	0.96 ± 0.00^{f}

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$). WAC: Water Absorption Capacity.

Similar observations were made by Olaitan *et al*. [11] where the bulk density of pearl millet porridge increased as the concentration of MLP increased among samples. Another study by Maha *et al*. [22] on the effect of different supplementation levels of soybean flour on pearl millet functional properties also observed an increase in the bulk density of the flour as levels of soybean increased. Bulk density plays a crucial role in the digestibility of foods, especially for infants. Among all the samples, PmMD2 stands out as the most suitable choice due to its lowest bulk density. On the other hand, the sample with the highest bulk density (PmMP2) will take up less space per unit weight compared to the other samples, making it more commercially viable than the rest.

Water Absorption Capacity (WAC)

The water absorption capacity is the measure of the volume occupied by starch polymer after swelling in excess water. It represents the ability of a product to associate with water where water is finite [23]. Water absorption capacity provides information about the ease of a product to absorb water and therefore gives a predetermination of storage methods to be used. To avoid moisture from destroying the product airtight is often used [24].

In the current study, there was no significant difference in water absorption capacity (*$p>0.05$*) between the samples in WAC as indicated in Table 3. The values ranged from 8.48g/g to 8.69g/g. In a study by Olaitian *et al*. [11] on the Quality evaluation of Complementary food from MLP and pearl millet there was a significant difference in water absorption capacity among the samples. The WAC values in the study increased as the amount of MLP concentration increased. A significant difference among the samples was reported in another study by Dendegh *et al*. [19] on the evaluation of stiff porridge from pearl millet and African Yam Bean, the samples that had African Yam Bean had higher values compared to the control samples. A high amount of protein and carbohydrates was mentioned as a possible cause of the results. A study by Haile *et al*. [25] observed that as the amount of OFSP flour increased in the Bulla composite flour the WAC also increased. This indicated that OFSP has high WAC. Similar observations were made in this study as the samples that contained OFSP had higher values of WAC in comparison with the samples that did not contain OFSP.

VISCOSITY

Viscosity refers to the thickness or resistance to the flow of a fluid or semi-solid substance. Starch is the major contributor to the viscosity of any particular food. Upon heating, starch granules in the flour absorb water, swell, and release starch molecules that create a network that increases the viscosity of the porridge. Particle size, hydration, cooking time, and temperature are factors that affect viscosity.

In the current study, there was a significant difference in viscosity between the samples ($p<0.05$). The values ranged from 2.2 dpas of the control sample PmDP to 0.59 dpas of the sample PmMD2. It was observed that viscosity increased as the amount of OFSP increased. Samples that contained OFSP had higher viscosity scores in comparison with those that contained dates. This could be due to the starchy nature of OFSP that gelatinizes when heated and contributes to the viscosity of pearl millet. According to Haile *et al*. [25], viscosity of Bulla composite flour increased as the amount of OFSP increased among the samples. The high-water absorption capacity of OFSP was mentioned to be a possible cause of the results. The findings from the current study are contrary to the those observed by Mukama [32] in which the addition of OFSP into millet flour decreased the viscosity values. This was due to a significant decrease in the amounts of millet in the flour as significant amounts of OFSP were added to the flour mixtures.

Sensory attributes

Color

There was a significant difference ($p<0.05$) in color for all the samples under study as indicated in Table 4. The difference was influenced by the intense orange color of the orange-fleshed sweet potato and green color of the Moringa leaves that greatly impact the color among the samples. The scores of colors ranged from 1.8 to 6.4.

Table 4: Acceptability of the Porridge samples

Samples	Color	Aroma	Taste	Overall Acceptability
PmDP	6.4 ± 0.6^{e}	4.9 ± 1.1^{g}	5.1 ± 1.1^{k}	4.7 ± 1.1^{o}
PmMD1	3.1 ± 1.2^{b}	4.1 ± 1.0^{fg}	3.1 ± 1.8^{i}	2.7 ± 1.4^{l}

PmMD2	2.5 ± 1.1^{ab}	4.1 ± 0.9^{fg}	2.7 ± 1.1^{i}	2.4 ± 0.9^{l}
PmMD3	1.8 ± 0.7^{a}	3.7 ± 1.9^{f}	3.4 ± 0.8^{i}	2.5 ± 1.8^{m}
PmMP1	4.3 ± 1.2^{c}	4.4 ± 1.4^{fg}	3.6 ± 1.7^{i}	4.0 ± 2.0^{m}
PmMP2	5.2 ± 0.8^{d}	6.4 ± 0.6^{h}	6.1 ± 1.0^{k}	5.9 ± 1.2^{no}
PmMP3	4.1 ± 1.3^{c}	4.9 ± 1.4^{g}	5.0 ± 1.6^{j}	5.1 ± 1.9^{mn}

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$).

Acceptability in color in the current study, was contributed by the orange color from OFSP as it was observed that acceptability increased as the amount of OFSP increased. This is comparable to [9] who formulated pearl millet flour-based cookies supplemented with mung bean and orange fleshed sweet potato flours observed that, the acceptability of cookies improved with the inclusion of OFSP. In current study, the samples that did not contain OFSP had lower scores (Table 4) due to the unusual green color from the chlorophyll pigment of Moringa leaf powder that amplified during the drying and cooking process. It was also reported in other studies that the inclusion of Moringa leaves lead to poor acceptance of products due to the green color [11],[26] and this is in line with what was observed in current study.

Color is one of the important attributes that leads a consumer to decide on liking of the product as it gives the very first impression. Color is used to evaluate the food's desirability and acceptability. It often triggers certain expectations on the mind of a consumer. Despite the fact that preference of color differs among people, it is important to put a high consideration in color of new products because people tend to compare the new product with those that are already in the market [18].

Taste

Taste or the perception of gustatory input is the most influential factor in a person's selection of a particular food as it surpasses all other attributes. The product taste can fall in one or two of the basics tastes that are sweet, salty, sour, bitter and umami. The sweet taste of the product observed in current study (Table 4) was influenced by OFSP and dates powder. The bitter taste could have been influenced by MLP that was included in some formulations.

There was a significant difference in Taste ($p<0.05$) among samples that were contributed by both OFSP and MLP. The higher scores observed for Orange Flesh Sweet Potato) can be attributed to its natural sweetness, which has the ability to mask the bitter taste of Moringa leaf powder as seen in PmMP2 scoring 6.1 of taste as opposed to PmMD2 which gave 2.7 taste score (Table 4). Both contained moringa leaf powder indicated as M and Orange Flesh Sweet Potato indicated as P in the formulations. This is in contrast to the samples that included dates,

where the sweetening effect was not present. A study by Gebretsadikan *et al*. [27] reported that the sweet nature of OFSP allowed the incorporation of up to 7% of MLP in the porridge sample.
It was observed that dates containing samples had low rating scores. This implies that date powder did not mask the bitter taste of Moringa leaf powder resulting in overall bitter taste of the samples as it is with Orange Flesh Sweet Potato. The study by Olaitan *et al*. [11] reported the least preference for taste of porridge samples due to the inclusion of MLP. Similar observation is reported in other study by Sengev *et al*. [28] who reported least preference in taste for moringa-supplemented wheat bread.

Aroma
Aroma is a fundamental segment of taste together with the general acceptability of the food prior to consumption. As indicated in Table 4, there existed a significant difference among the samples ($p<0.05$). The highest aroma score of 6.4 was obtained with the formulation sample (PmMP2) having the lowest amount of MLP and high amount of OFSP (2%MLP, 10%OFSP). A similar observation was reported by Gebretsadikan *et al*. [27] and Dachana *et al*. [29] for Moringa fortified biscuits and composite porridge respectively. The lowest aroma score of 3.7 was observed in the sample that contained the highest amount of MLP (3%) as observed in Table 4. Studies have reported lower ratings in complementary foods that had MLP from 5% and above [11], [26]
MLP in the porridge samples highly affected the aroma due to the leafy and herbal-like smell that it possesses when cooked. This turns out to be a turn-off to consumers as it brings a sense of medicine and not food Boateng *et al*., [26].

Overall acceptability
There was a significant difference ($p<0.05$) in overall acceptance among the samples. The sample with (88%Pm: 2%MLP:10%OFSP) had the highest score (Table 4). A similar observation was made by Gebretsadikan *et al*. [27] where the fortified porridges with high OFSP and/or soybean proportions with less moringa received the highest overall acceptability. The samples that contained higher amounts of MLP had the lowest scores. Studies done by Olaitan *et al*. [11]; Sengev *et al*. [28]; Dachana *et al*. [29] and Hedhili *et al*. [30] and reported that as the concentration of Moring leaf powder in the sample increased the overall acceptability decreased. The reason for this inverse relationship is generally the deep green color of Moring leaf powder, its leafy herbal odor, and taste that makes the consumer to be less attracted. Another reason could be due to the adoption to specific crops for porridge processing in many communities, the use of uncommon crops like Moring leaf powder has a great impact on changing their sensory attributes and this makes it hard to be accepted in short period. It can be expressed that the incorporation of Moring leaf powder in foods should be in moderation so as to increase the acceptability of products.

Quantitative Descriptive Analysis
In this study, there was no significant difference in the intensity of aroma, thickness, and grittiness together with color at ($p> 0.05$). A significant difference was only observed in sweetness among the samples. The values for sweetness in ranged from (1.9 to 4.2) as seen in Table 5.

Table 5: Mean intensity scores of porridge samples by the sensory panel

Samples	Color	Aroma	Sweetness	Thickness	Grittiness
PmDP	1.4±0.5[a]	3.8±0.9[b]	4.2±0.7[d]	1.0±0.0[e]	2.9±1.5[f]
PmMD1	1.4±0.5[a]	3.8±1.1[b]	2.3±0.8[c]	1.2±0.4[e]	2.8±0.6[f]
PmMD2	1.6±0.5[a]	3.2±0.9[b]	2.0±0.8[c]	1.2±0.4[e]	3.0±1.0[f]
PmMD3	1.6±0.5[a]	3.1±0.9[b]	2.3±1.1[c]	1.1±0.3[e]	2.5±0.5[f]
PmMP1	1.5±0.5[a]	3.1±0.9[b]	1.9±0.9[c]	1.1±0.3[e]	2.7±0.9[f]
PmMP2	1.4±0.5[a]	3.2±0.6[b]	2.9±1.1[cd]	1.2±0.4[e]	3.0±1.3[f]
PmMP3	1.5±0.5[a]	3.1±0.7[b]	2.4±0.8[c]	1.1±0.3[e]	2.9±1.1[f]

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$)

Key: PmDP (50%pearl millet:15%dates:35%orange fleshed sweet potato), PmMD1(90%pearl millet:2.5%Moringa leaf powder:7.5%dates), PmMD2(95%pearl millet:2.5%Moringa leaf powder:2.5%dates), PmMD3(88%pearl millet:3%Moringa leaf powder:9%dates), PmMP1(95.5%pearl millet:2%Moringa leaf powder:2.5% orange fleshed sweet potato), PmMP2(88%pearl millet:2%Moringa leaf powder:10% orange fleshed sweet potato), PmMP3(95%pearl millet:2.5%Moringa leaf powder:2.5% orange fleshed sweet potato).

The highest score in sweetness intensity was with the control sample (50%PM+15%DT+35%OFSP) which contained higher amounts of OFSP and dates than all other samples. The sample that scored the least contained equal amounts of MLP and OFSP (95%PM+2.5%MLP+2.5%OFSP) which could be the reason that its sweetness was altered.

PCA BIPLOT

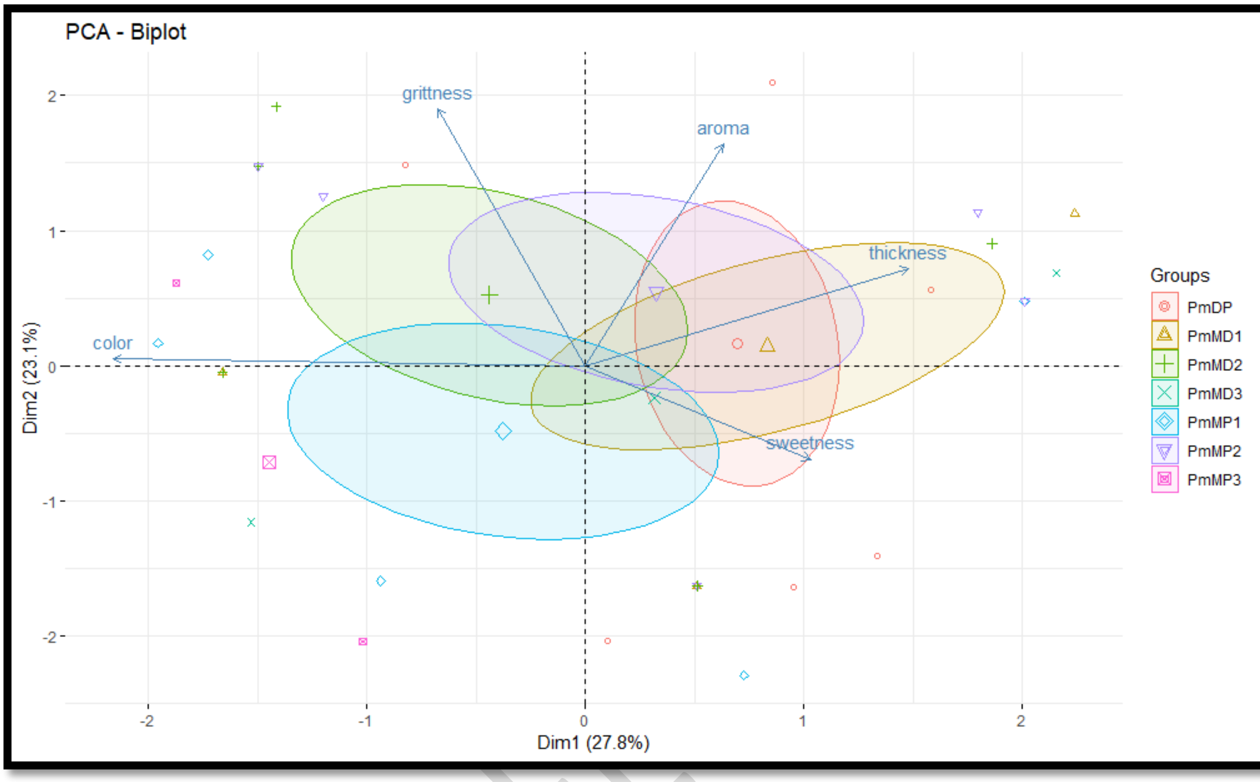


Figure 2**:** Bi-plot of PCA showing an association between samples and attributes

From Figure 1, the bi-plot of principal component analysis shows that, PC 1 accounts for 27.8% of the variation and PC 2 accounts for 23.1% of the variations. The biplot shows that the attributes of aroma and thickness are closely associated together as they are facing the same direction. This is unlike the attributes of grittiness and sweetness that show no association with each other as each faces its own direction. The attribute of color shows no association with other attributes as it has the longest arrow drawn far away from other attributes that are shown to be a little bit closer to each other.

The sample PmDP was strongly associated with sweetness, thickness, and aroma. The sample PmMD1 was highly associated with thickness. There was a high association between the sample PmMP2 with the attributes of grittiness, aroma, and thickness. The attribute of sweetness was slightly associated with the sample PmMP2. The sample PmMD2 is associated with all the attributes but largely with grittiness and color. The sample PmMP1 associated is the only sample that is associated highly with color while having very little association with attributes. The sample PmMD2 had the lowest preference score from consumers. It was characterized by levels of deep green color, grittiness, and aroma that was herbal and leafy from MLP that consumers did not like.

Conclusion

This study shows that functional parameters have an influence on the acceptability of product. It is therefore important to ensure that the functional parameters are considered and worked on well so as to promote acceptability of the product. Individual sensory attributes such as color, aroma and taste contributed to the overall acceptability of the product. The functional parameters not only indicate sensory acceptability but also play a crucial role in determining storage, transportation, and distribution characteristics.

The inclusion of Moringa leaf powder into the samples has shown a significant change color and taste. Its deep green color and bitter taste has affected the acceptability of the product in terms of color and taste. The addition of Dates and Orange Fleshed Sweet Potato improved the acceptability of samples. It has also shown great results in improving the functional parameters of the porridge samples. For its good nutritional profile, and sensory and functional qualities it should be used often in the development of other food products. The formulation Pm:M:P2 (88%pearl millet:2%Moringa leaf powder:10% orange fleshed sweet potato) was the most accepted sample and recommended for toddlers aging 1-3 years. Considering high nutritive profile of Moringa oleifera it should be added in complementary foods. Addition of Moringa in foods should be in very small amounts and added with other ingredients that could help to mask the color and bitter taste of Moringa.

REFERENCES

1. Abeshu, Motuma Adimasu, Azeb Lelisa, and Bekesho Geleta. Complementary feeding: review of recommendations, feeding practices, and adequacy of homemade complementary food preparations in developing countries–lessons from Ethiopia. Frontiers in nutrition. 2016;(4):41.
2. World Health Organization. Complementary feeding: report of the global consultation, and summary of guiding principles for complementary feeding of the breastfed child. World Health Organization. 2003.
3. Mkambula, Penjani, Mduduzi NN Mbuya, Laura A. Rowe, et al. The unfinished agenda for food fortification in low-and middle-income countries: quantifying progress, gaps and potential opportunities. Nutrients.2020;12(2):354.
4. Makame, James, Henriette De Kock, and Naushad M. Emmambux. Nutrient density of common African indigenous/local complementary porridge samples. LWT.*2020;*133:109978.
5. Bani Hani, Nabeel, Fakher J. Aukour, and Mohammed I. Al-Qinna. Investigating the Pearl Millet (Pennisetum glaucum) as a Climate-Smart Drought-Tolerant Crop under Jordanian Arid Environments. Sustainability. 2022;(14):12249.
6. Rockwood, J. L., B. G. Anderson, and D. A. Casamatta. Potential uses of Moringa oleifera and an examination of antibiotic efficacy conferred by M. oleifera seed and leaf extracts using crude extraction techniques available to underserved indigenous populations. International Journal of Phytotherapy Research.2013;3(2):61-71.
7. Kamran, Muhammad, Shabbir Hussain, Muhammad Amin Abid, Shahzada Khurram Syed, Muhammad Suleman et al.. Phytochemical composition of moringa oleifera its nutritional and pharmacological importance. Postepy Biologii Komorki. 2020; 47(3):321-334.
8. Hasan, Mahmood Ul, Aman Ullah Malik, Sajid Ali, Amna Imtiaz, Anjum Munir, Waseem Amjad, and Raheel Anwar. Modern drying techniques in fruits and vegetables to overcome postharvest losses: A review. Journal of Food Processing and Preservation. 2019;43(12).
9. Bello, Florence A., Mercy A. Folademi, and Lawrence J. Iwok. Development of pearl millet flour-based cookies supplemented with mung bean and orange fleshed sweet potato flours.The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology. 2022;(46):155-168.

10. Singh, Shubhi, Rishibha Gupta, Sonam Chawla, et al. Natural sources and encapsulating materials for probiotics delivery systems: Recent applications and challenges in functional food development. Frontiers in Nutrition.2022;9: 971784.
11. Olaitan, N. I., M. O. Eke, E. M. Uja, and E. A. Oja. Quality evaluation of complementary food formulated from Moringa Oleifera leaf powder and pearl millet (Pennisetum Glaucum) flour. International Journal of Engineering and Science. 2014;3(11):59-63.
12. Malla, Janet Kajuju, Sophie Ochola, Irene Ogada, and Ann Munyaka. Nutritional Value and Sensory Acceptability of M. oleifera Fortified Finger Millet Porridge for Children with Cerebral Palsy in Nairobi County, Kenya. Journal of Food Research.2021;10(5):1-36.
13. Falade, Kolawole O., and Oluwakemi J. Solademi. Modelling of air drying of fresh and blanched sweet potato slices. International journal of food science & technology.2010; 45(2):278-288.
14. Nefale, Fulufhelo E., and Mpho E. Mashau. Effect of germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge. Asian Journal of Applied Sciences.2018;6(5).
15. Onwuka, Gregory I. Food analysis and instrumentation*:* theory and practice. Napthali prints. 2005.
16. Anderson, R. A., H. F. Conway, V. F. Pfeifer, and E. L. Griffin. Roll and extrusion-cooking of grain sorghum grits. Cereal Science Today. 1969;(14):372-376.
17. Meilgaard, M. C., Civille, G. V. and Carrison, B.T. Sensory Evaluation Technique, fourth edition. CRC press, Taylor and Francis group, USA. 2006. 464.
18. Lawless, Harry T., and Hildegarde Heymann. Sensory evaluation of food: principles and practices. New York: Springer. 2010;2.
19. Dendegh, T. A., B. M. Yelmi, and R. A. Dendegh. Evaluation of stiff porridge (Ruam nahan) produced from composite flour blends of pearl millet (Pennisetum glaucum) and African yam bean (Sphenostylis stenocarpa). Asian Food Science Journal. 2021;9:63-77.
20. Krishnan, Rateesh, Usha Dharmaraj, R. Sai Manohar, and N. G. Malleshi. Quality characteristics of biscuits prepared from finger millet seed coat based composite flour. Food chemistry.2011; 129(2):499-506.
21. Olu, Malomo, O. A. B. Ogunmoyela, O. O. Adekoyeni, O. Jimoh, S. O. Oluwajoba, and M. O. Sobanwa. Rheological and functional properties of soy-poundo yam flour. International journal of food science and nutrition engineering. 2012;2(6):101-107.

22. Maha AM, Ali, Abdullahi H. El, Elkhalifa Abd Elmoneim O, Mallasy Limya O, and Babiker Elfadil E. Effect of different supplementation levels of soybean flour on pearl millet functional properties. Food and Nutrition Sciences. 2012.
23. Chinma, C. E., J. O. Abu, S. James, and M. Iheanacho. Chemical, functional and pasting properties of defatted starches from cowpea and soybean and application in stiff porridge preparation. Nigerian Food Journal.2012;30(2):80-88.
24. Ijarotimi, O. S. and Ashipa, F. Chemical composition, sensory and physical property of home processed weaning food based on low cost locally available food materials. International Journal of Molecular Medicine and Advance Sciences. 2005; 1(3): 213-219.
25. Haile, Abebe, Martha Geribo, and Esayas Kinfe. Evaluation of porridge made from composite flour of orange-fleshed sweet potato and Enset (Bulla) flours. Agriculture and Food Sciences Research.2016;3(1):37-44.
26. Boateng, Laurene, Wilhemina Quarpong, Agartha Ohemeng, Matilda Asante, and Matilda Steiner-Asiedu. Effect of complementary foods fortified with Moringa oleifera leaf powder on hemoglobin concentration and growth of infants in the Eastern Region of Ghana. Food science & nutrition. 2019;7(1):302-311.
27. Gebretsadikan, Tirhas M., Geremew Bultosa, Sirawdink Fikreyesus Forsido, and Tessema Astatkie. Nutritional quality and acceptability of sweet potato–soybean–moringa composite porridge. Nutrition & Food Science.2015; 45(6):845-858.
28. Sengev, Abraham I., Joseph O. Abu, and Dick I. Gernah. Effect of Moringa oleifera leaf powder supplementation on some quality characteristics of wheat bread. Food and nutrition sciences.2013; 4(3):270.
29. Dachana, K. B., Jyotsna Rajiv, D. Indrani, and Jamuna Prakash. Effect of dried moringa (Moringa oleifera lam) leaves on rheological, microstructural, nutritional, textural and organoleptic characteristics of cookies. Journal of Food Quality. 2010; 33(5):660-677.
30. Hedhili, Amel, Samuel Lubbers, Elias Bou-Maroun, Francine Griffon, Babatope Ebenezer Akinyemi, Florence Husson, and Dominique Valentin. Moringa Oleifera supplemented biscuits: Nutritional values and consumer segmentation. South African Journal of Botany. 2021;138:406-414.
31. Scholz-Ahrens, Katharina E., Frank Ahrens, and Christian A. Barth. Nutritional and health attributes of milk and milk imitations. European journal of nutrition.2020; 59:19-34.
32.