Asian Food Science Journal

Volume 22, Issue 7, Page 15-24, 2023; Article no.AFSJ.101147
ISSN: 2581-7752

Sensory, Proximate and Mineral Properties of Smart Baby-Led Weaning Foods from Millet, Soybean and Ripe Banana Flour Blends

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Authors' contributions

This work was carried out in collaboration among all authors. Material preparation, data collection and analysis were performed by authors AAO and MS. Technical interpretation of data was equally contributed by the authors. The first draft of the manuscript was compiled by author AOO and first proofread by author YAJA. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2023/v22i7644

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101147

Original Research Article

Received: 11/04/2023
Accepted: 13/06/2023
Published: 15/06/2023

ABSTRACT

Aim: The need for formulating and developing smart baby-led weaning (BLW) foods from millet, soybean and ripe banana flour blends as alternative complementary foods inspired this study, which had no documentation in literatures.
Place and Duration of Study: Department of Food Technology, Auchi Polytechnic, Auchi, Nigeria from June 2022 to January 2023.

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Methodology: Smart BLW foods were formulated from millet, soybean and ripe banana flour blends and coded as WMF (100% whole millet flour), MSB1 (60% millet; 20% soybean; 20% ripe banana) and MSB2 (50% millet; 30% soybean; 20% ripe banana). The sensory, proximate and mineral compositions of the foods formulated were compared with those of commercial weaning food (CWF).
Results: MSB1 and MSB2 competed favourably with CWF in terms of texture, general acceptability, colour, aroma and taste attributes with high negative deviation most noticeable in WMF ($P < 0.05$), and exhibited acceptable shelf-life and stability. The ash contents ranged from 1.16±0.02% (WMF) to 2.83±0.02% (MSB2). Increase in fat content in MSB1 to CWF was ≈534%, MSB2 to CWF was ≈492%, MSB1 to WMF was ≈385% and MSB2 to WMF was ≈353% while their protein abundances were in the ratios 1:3.6 for CWF:MSB1, 1:5.9 for CWF:MSB2, 1:2.4 for MWF:MSB1 and 1:3.9 for MWF:MSB2. Generally, MSB1 and MSB2 were appropriate sources of Na, K, Ca, Mg and Zn compared to CWF and WMF in providing adequate intake (AI) and recommended daily allowance (RDA) of these minerals in both infants and children in the age classes of 0-6 months, 7-12 months and 1-3 years.
Conclusion: MSB1 and MSB2 exhibited better intrinsic properties than WMF when compared with CWF. MSB1, however had better general performances than MSB2 and therefore, was recommended as the best smart BLW food formulation from this research.

Keywords: Smart BLW; shelf-life; adequate intake; complementary foods; soybean; ripe banana.

ABBREVIATIONS

CWF	:	*100% commercial weaning food*
WMF	:	*100% whole millet flour*
MSB1	:	*50% millet; 30% soybean; 20% unripe banana)*
MSB2	:	*60% millet; 20% soybean; 20% unripe banana)*
BLW	:	*Baby-Led Weaning*
FAO/WHO/UNU	:	*Food and Agriculture Organization/World Health Organization/United Nations University*

1. INTRODUCTION

At the transitional phase when a child is weaned from breast milk to adult foods, easy to digest supplements are required along with breast milk until the child is ready to eat semi-solid or fully adult foods. This gives room for the introduction of complementary foods that can meet the nutritional requirements of the growing child [1], but do not take the place of breast milk or modified milk, but serve as a complement to it [2,3]. Traditionally, complementary foods are gradually introduced to infants, starting with purees and mashed-up foods by spoon-feeding or hand-feeding to aid and enhance their mastication and swallowing ability [4].

Baby-led weaning (BLW), as a smart alternative to traditional approach of complementary foods, is a method that allows the babies feed themselves with finger foods from age of 6 months to 12 months [4,5]. Smart BLW food provides nutritional gains, increase in children's grasping precision, intense sensory and motor coordination, independent meal participation and pleasurable eating [2,6,7].

Over the years, the dominance of wheat in bakery and pasta industries is adduced to its gluten-forming proteins and good textural properties [8-10], but not without health disorders such as celiac disease, and high cost of importation. The rise in gluten-related disorders caused by wheat has called for its replacement by blend of flours [9,11,12], which is a mixture of flours from tubers and/or legumes and/or cereal [13] with or without wheat [14]. The flour blends should be one that is readily available, culturally acceptable, affordable and able to replace wheat flour in terms of nutrition and functionality [15].

Pearl millet, an underutilized crop with botanical name *Pennisetum glaucum* (L.) R. Br. Is a cultivated small-grain, topical cereal grass. It is locally called barja in India and gero in Northern Nigeria (Hausa language) [16]. Pearl millet (*Pennisetum glaucum* (L.) R.Br.) is a sustainable and underutilized food. Pearl millet could be used as a cheaper source of flour as compared to other cereals for developing functional foods [17]. In addition to its nutritional quality and being gluten free, millet has been reported to have several health benefits such as prevention of cancer, cardiovascular diseases, reducing tumor incidence, lowering blood pressure, delaying gastric emptying and supplying gastro intestinal bulk [18,19].

Soybean (*Glycine max*) is a native legume in East Asia, probably China. Oil, meal and variety of non-fermented and fermented soy foods are the soybean products [20]. Soybean serves as both sustenance and feed sources because of its high protein content (40%), good dietary quality, high oil content (20%), together with various useful supplements and bioactive variables [21]. Increase in soy foods consumption has been encouraged in order to promote heart health, and reduce the risk of breast and prostate cancer [22].

Banana (*Musa sp*.), either ripe or unripe, is one of the most cultivated tropical fruit globally [23]. Banana is a gluten-free food [2,3] with enhanced nutritional and physiological values to human health [24], abundance of dietary fibres, vitamins A, C and B_6, essential minerals such as K, P, Mg, Zn, bioactive compounds such as phenolic compounds, and resistant starch [25,26].

This study was aimed at formulating and developing smart baby-led weaning foods from millet, soybean and ripe banana flour blends as an alternative to traditional complementary foods, which have not been reported or documented in literatures. The sensory attributes, proximate compositions and mineral compositions of the flour blends were evaluated to ascertain their nutritional quality as smart baby-led weaning foods.

2. MATERIALS AND METHODS

2.1 Sources of Materials

Millet and soybean were commercially purchased from Uchi market, Etsako-West Local Government Area, Edo State, Nigeria and green (unripe) banana was freshly harvested from a farm in Owan-West Local Government Area, Edo State, Nigeria. The crops were used for research purpose only according to international chemical methods. All reagents used were of analytical grade and were used as purchased.

2.2 Preparation and Formulation of Flour Blends

The standard method described by Fikiru et al. [27] was adopted to prepare millet flour with slight modifications. The millet grains were cleaned by sorting, washed and soaked in water (1:4 w/v) for 72 h at room temperature, followed by milling and sieving with muslin bag. The residue was oven-dried at 60 ^{o}C for 36 hrs (plus II Sanyo Gallenkamp Plc, UK). The dried sample was aseptically milled in a laboratory blender (Moreal KM 9010, Kenwood Electronic Hertfordshire, UK) and sieved through 200 mm sieve to obtained fermented millet flour. Soybeans grains were sorted, washed, soaked at 72 hrs at room temperature, rinsed, oven-dried (plus II Sanyo Gallenkamp Plc, UK), roasted, dehulled, milled in a laboratory blender (Moreal KM 9010, Kenwood Electronic Hertfordshire, UK) and sieved through 200 mm sieve to obtain soybean flour. Ripe bananas were sorted, peeled, mashed to paste and packaged prior to weaning food formulation [28].

2.3 Preparation of Weaning Foods

The protein daily dietary intake requirement for infants (1.47-1.15 g/kg of protein), according to FAO/WHO/UNU [29] was considered in preparing thick pap, spread thin sheet, baked to flakes and milled from the flours of millet and soybean and banana paste. The flour blends of the meal were coded as shown in Table 1.

2.4 Sensory Attributes

All the sensory analyses were conducted in a sensory laboratory (Department of Food Technology, Auchi Polytechnic, Auchi) with adequate lighting and odour-free environment. Panelists were selected based on familiarity with control samples, recognition and perception of common odours. Each formulated weaning meal was prepared by dispersing flour in water (1:4 w/v) at 100 ^{o}C for 10 min. The reconstituted formulated cookies samples and the control cookies samples were coded and presented to 30 untrained panelists. Potable water at room temperature was provided for mouth rinsing in between successive evaluation. Sample acceptance (color, texture, taste, aroma, mouldability and general acceptability) were rated on a scoring scale of 1 to 9 where 1 = dislike extremely and 9 = like extremely. Panelists made their responses on score sheets designed in line with the test procedures [30].

Table 1. Formulation of weaning foods

Sample Code	Formulation
CWF	100% Commercial Weaning Food
WMF	100% Whole Millet Flour
MSB1	60% Millet; 20% Soybean; 20% Ripe Banana
MSB2	50% Millet; 30% Soybean; 20% Ripe Banana

Obtained as the best mixture using multiple RSM design 7.0

2.5 Proximate Analysis

The crude protein, crude fibre, ash, moisture and fat contents of the cookies were determined using the standard methods of Association of Official Analytical Chemists [31]. Carbohydrate was obtained by difference 100% – (moisture + protein + fat + ash + fibre)%.

2.6 Mineral Analysis

Each weaning flour (1.0 g) was weighed into a crucible, transferred to a muffle furnace and ashed at 550 ^{o}C for 6 hrs. The ash content was dissolved in 10 mL of 0.1 M HCl solution, the crucible was rinsed three times with 0.1 M HCl and made up to 100 mL with deionized water. The clear aliquot of digest was analyzed for sodium, potassium, calcium, magnesium, iron and zinc, using Atomic Absorption Spectrophotometer (AAS Model SP9, Pye Unicam Ltd, Cambridge, UK) [32].

2.7 Statistical Analysis

IBM Statistical Package for Social Science (SPSS 26.0) software was used for statistical analysis of the data obtained for mean comparison, using Duncan's least significant test and one-way analysis of variance (ANOVA) at 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Sensory Attributes

The sensory attributes of the flour blends for baby-led weaning food, in terms of colour, texture, aroma, taste and general acceptability are presented in Table 2. The texture and general acceptability attributes of whole millet flour (WMF), used as negative control, 60% millet 20% soybeans 20% banana flour (MSB1) and 50% millet 30% soybeans 20% banana (MSB2) are similar with commercial weaning food (CWF), used as positive control ($P < 0.05$). However, low significant differences are observed among the samples in terms of their colour, aroma and taste attributes ($P < 0.05$), which are most noticeable in WMF. Thus, MSB1 and MSB2 have similar colour, texture, aroma, taste and general acceptability to CWF.

MSB1 and MSB2 have similar colour, texture, aroma, taste and general acceptability to CWF. Improvement in the nutritional value of sample MSB1 and MSB2 through incorporation of soybean and ripe banana could be adduced as a reason for the observed high preference by the panelist for the two samples as attested to by the relatively high sensory scores when compared with the control samples [2,24].

3.2 Proximate Compositions

The proximate composition of complementary foods from millet, soybean, banana flour blends and commercial weaning food are shown in Table 3. The percentage proximate compositions (moisture content, ash content, fat content, crude fibre, crude protein and carbohydrate by difference) of the weaning foods formulated (WMF, MSB1 and MSB2) are significantly different among themselves and from CWF ($P < 0.05$). The moisture content increases from 1.55±0.03% in CWF to the peak of 11.08±0.11% in WMF. The ash contents of the samples range from 1.16±0.02% in WMF to 2.83±0.02% in MSB2. Except for WMF, both MSB1 and MSB2 have higher ash content than CWF. The fat content of the weaning food samples increases from 2.80±0.15% (CWF) to 17.75±0.12% (MSB2). Crude fibre (%) is lowest in CWF (0.21±0.01) and highest in MSB1 (4.78±0.09). Percentage crude protein ranges from 4.28±0.06 in CWF to 25.33±0.01 in MSB2. Carbohydrate content is by difference, which ranges from 42.99±0.24% in MSB2 to 88.92^{a}±0.12% in CWF.

Table 2. Sensory attributes commercial and formulated weaning foods

Attribute	Sample			
	CWF	WMF	MSB_1	MSB_2
Colour	4.50^{a}±0.85	3.70^{b}±0.67	4.10^{ab}±0.88	4.50^{a}±0.71
Texture	4.80^{a}±0.42	4.00^{a} ±0.82	4.30^{a}±0.67	4.20^{a}±1.23
Aroma	4.40^{a}±0.70	3.70^{b}±0.48	4.60^{a}±0.52	4.30^{a}±0.82
Taste	4.80^{a}±0.42	4.10^{b}±0.74	4.50^{a}±0.71	4.20^{ab}±0.79
General Acceptability	4.50^{a}±0.71	4.10^{a}±0.57	4.40^{a}±0.52	4.50^{a}±0.53

Results are the means of triplicate determination ± standard deviation values in the same row with the same superscripts letters (a > b) are not significantly different (P < 0.05)

Table 3. Proximate compositions and formulated weaning foods

Sample	Proximate Composition (%)					
	Moisture Content	Ash Content	Fat Content	Crude Fibre	Crude Protein	Carbohydrate By Difference
CWF	1.55^{d}±0.03	2.24^{c}±0.01	2.80^{d}±0.15	0.21^{d}±0.01	4.28^{d}±0.06	88.92^{a}±0.12
WMF	11.08^{a}±0.11	1.16^{d}±0.02	3.66^{c}±0.02	1.13^{c}±0.04	6.42^{c}±0.01	76.56^{b}±0.16
MSB_1	9.06^{b}±0.05	2.60^{b}±0.15	16.57^{b}±0.06	4.78^{a}±0.09	15.44^{b}±0.04	51.54^{c}±0.09
MSB_2	6.56^{c}±0.18	2.83^{a}±0.02	17.75^{a}±0.12	4.36^{b}±0.23	25.33^{a}±0.01	42.99^{d}±0.24

Results are the means of triplicate determination ± standard deviation values in the same column with the same superscripts letters (a > b > c > d) are not significantly different (P < 0.05)

From the results obtained for moisture contents of the samples, CWF has the least moisture content, indicating that CWF has higher shelf-life than all the weaning foods formulated. The lower the moisture content the higher the shelf-life and stability of the product. Moisture content of 9-10% has been documented for wheat flour for stability and long shelf-life [33]. Except for WMF, both MSB1 and MSB2 possess higher ash content than CWF. Ash content of food is an indication of relative availability of minerals in it; the higher the value the higher the relative abundance of minerals. This inference, however, is not sufficient to identify the type of minerals present and to quantify their relative abundance. The fat content of the weaning food samples is highest in CWF (2.80±0.15%) and lowest in MSB2 (17.75±0.12%). The percentage increase in fat content, due to the incorporation of soybean in soybean- and banana-based MSB1 to CWF is approximately 534%, MSB2 to CWF is approximately 492%, MSB1 to WMF is approximately 385% and MSB2 to WMF is approximately 353%. This difference is justified by the relative amount of soybean in MSB1 and MSB2. Soybean is rich in polyunsaturated edible fats, mainly omega-6 fatty acids and omega-3 fatty acids [34]. CWF has the least crude fibre (0.21±0.01) while MSB1 the highest (4.78±0.09). The differences in crude fibre may be due to the incorporation of soybean and banana, which are good sources of fibre [35,36]. Soybean has been documented, not only as a good source of polyunsaturated fats, but of dietary fibre [36,37]. The values obtained are below RDA of 10 g/day for children [38]. Both soybean- and banana-based baby-led weaning foods formulated (MSB1 and MSB2) are extremely rich in protein compared to both CWF and WMF, which occurs in ratios 1:3.6 for CWF:MSB1, 1:5.9 for CWF:MSB2, 1:2.4 for MWF:MSB1 and 1:3.9 for MWF:MSB2. These differences are not unexpected due to relative abundance of proteins in soybean [37]. Proteins are important both in quality and quantity for rapid growth and development of a child. Carbohydrate content is by difference and is lowest in MSB2 (42.99±0.24%) and highest in CWF (88.92^{a}±0.12%). Carbohydrate content is an important factor of complementary food necessary for energy requirement and rapid growth. Low values of carbohydrate by difference in MSB1 and MSB2 is their richness in fats, which also serve as a good source of energy.

3.3 Mineral Compositions

The minerals detected in the weaning food samples are sodium (Na), potassium (K), calcium (Ca), manganese (Mn), iron (Fe) and zinc (Zn) (Fig. 1). Generally, soybean- and banana-based baby-led weaning foods formulated (MSB1 and MSB2) are better sources of Na, K, Ca, Mg and Zn than both CWF and WMF. Also, MBS2 is the richest in Fe among all the samples. The iron and the zinc are the least abundant out of all the mineral analyzed ranging from 0.24 ppm Fe (WMF) to 0.32 ppm Fe (MSB2) and from 0.50 ppm Zn (WMF) to 0.59 ppm Zn (MSB2). This is the confirmation of the relative abundance of ash contents in MBS1 and MBS2 (Table 3).

Sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and zinc (Zn) are more available in MSB1 and MSB2 than both CWF and WMF. Dietary sodium is needed by infants and children in very small quantity [39]. Depending on the age, RDA for Na is 110 mg/day for 0-6 months, 370 mg/day for 7-12 months and 800 mg/day for 1-3 years [39] with the view to effectively controlling the blood pressure [40]. Potassium, being the most abundant intracellular cation, maintains intracellular fluids balance and transmission of nerves in relation with sodium [41]. Importantly, lowering the blood pressure implies lowering the sodium intake and simultaneously increasing the potassium intake [41]. Adequate intake (AI) of potassium for infants 400 mg/day for 0-4 months, 600 mg/day for 6-12 months and 1100 mg/day for 1-4 years [42]. Getting enough calcium at infancy to adulthood is through adequate diet, which will prevent the risk of weak teeth and bones, and fractures in later life. Additional roles played by calcium in the body are clotting of blood, neuro-sensing, contraction and relaxation of muscles, release of hormones and maintaining normal heartbeat. Worthy of note is the richness of MSB1 and MSB2 in calcium compared to CWF. Adequate intakes (AIs) for 0-6 months, 7-12 months and 1-3 years are 200 mg/day, 260 mg/day and 700 mg/day respectively [43]. In case of magnesium, the AIs are Infants and children benefit immensely from adequate intake of magnesium. Deficiencies in magnesium result in loss of appetite, fatigue, nausea, muscle cramps, sleeplessness, hyperactivity, irritability, anxiety in infants and children [44]. AIs of magnesium are 30 mg/day, 80 mg/day and 170 mg/day 0-6 months, 7-12 months and 1-3 years respectively [45].

The Iron and the zinc are the least abundant out of all the mineral analyzed ranging from 0.24 ppm Fe (WMF) to 0.32 ppm Fe (MSB2) and from 0.50 ppm Zn (WMF) to 0.59 ppm Zn (MSB2). Infants and toddlers become more susceptible to anemia (iron deficiency), especially at 6-12 months due to increased exogenous iron requirements. Complementary foods with high calories, nutrient density and adequate iron content as well as high nutrient bioavailability can be used to prevent iron deficiency in infants and children [46]. For infants at <7 months, the adequate intake (AI) of iron is 0.27 mg/day while at 7-12 months, the RDA is 11 mg/day and at 1-3 years is 7 mg/day [46]. The biological functions of zinc are manifold, because it functions as a component of various enzymes in the maintenance of the structural integrity of proteins and in the regulation of gene expression [47]. It has general influences on cell growth, differentiation, immunity, cognition and reproduction [48]. On the other hand, RDA of zinc for infants aged 0-6 months is 2.0 mg, and it is 3.0 mg per day for young children aged 7-36 months [49].

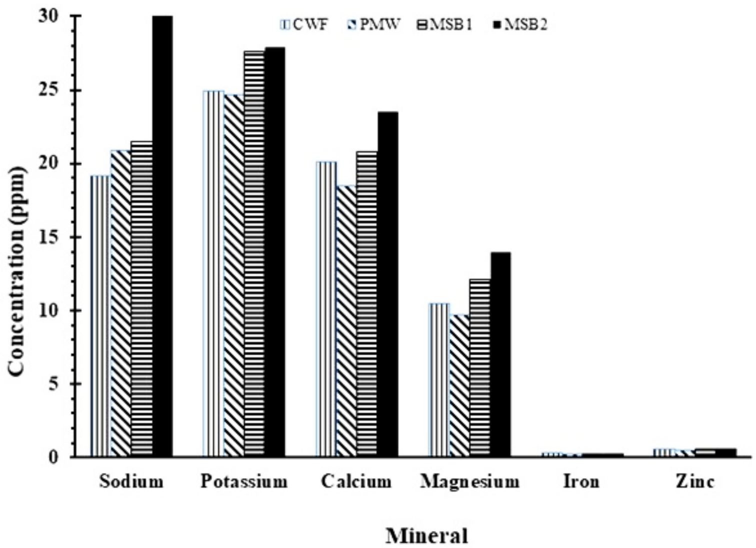

Fig. 1. Mineral compositions of commercial and formulated weaning foods

4. CONCLUSION

Infants and children need appropriate complementary foods, that is, smart baby-led weaning (BLW) foods to combat nutrient deficiencies at early period of life. This research has presented smart BLW foods formulated from blends of millet, soybean and ripe banana flours and made comparison with a commercial weaning food used as a control. The soybean- and ripe banana-based smart BLW foods formulated compete favourably with the commercial weaning food in terms of texture, general acceptability, colour, aroma, taste, acceptable stability and shelf-life. Their relative abundance in polyunsaturated fats, protein supersedes those of the commercial weaning food. The soybean- and banana-based smart BLW foods formulated (MSB1 and MSB2) are better sources of Na, K, Ca, Mg and Zn than both commercial weaning food and the whole millet food. MSB1 (50% millet; 30% soybean; 20% unripe banana), however has better performances than MSB2 (60% millet; 20% soybean; 20% unripe banana), and therefore, is recommended as a smart BLW food formulation from this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101147