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LOW-COST NUTRIENT-DENSE COMPOSITE FLOURS FOR CHILDREN AGED 1-5 YEARS DEVELOPED FROM LOCALLY AVAILABLE FOODS

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ABSTRACT

Childhood malnutrition persists in low-income countries due to inadequate diet diversity and nutrient density. For seasonal crops, consumers make food substitutions based on price variations which has dietary implications and can cause episodes of nutritional deficiencies. Locally available foodstuffs can be used to formulate low-cost nutritionally adequate food mixtures. Design-Expert® and Nutrisurvey software were used to generate nutrient-dense formulations for the dry season (n=2) and wet season (n=5) from low-cost locally available foods in Eastern Uganda (sweet potatoes, sorghum, soybeans, beans, sesame, groundnuts and maize). Composite flours of the formulations were prepared and cooked following the World Food Program (WFP) recommendations and consumer acceptability determined using a consumer panel (n=43). The most acceptable formulation for the dry season (D2) and the most acceptable formulation for the wet season (R5) were selected for the determination of functional properties (dispersibility, bulk density and water absorption index (WAI) and water solubility index (WSI)), pasting properties (peak viscosity, breakdown viscosity, final viscosity, setback viscosity and peak time), color and nutrient density (energy content, sugars, starch, protein, crude fat, fiber, ash, iron and zinc). D2 contained 25.35g of sorghum, 1.31g of soybeans, 4.34g of beans, 33.11g of sesame and 35.89g of groundnuts per 100g of formulation. R5 contained 4.95g of maize, 20.98g of sorghum, 5.49g of beans, 29.39g of sesame and 39.19g of groundnuts per 100g of formulation. The nutrient densities of D2 and R5 when cooked according to WFP recommendations were also determined. D2 and R5 had high dispersibility (77.2-76.8%), low water absorption index (1.7-2.0g/g) and high water solubility index (0.2-0.3g/g). The pasting properties indicated that the formulations form stable low viscosity pastes that can withstand breakdown during cooking and have high resistance to retrogradation on cooling. Cooked D2 (100g) contained 87.2kcal, 9.5g starch, 2.3g sugars, 5.8g protein, 1.6g fat, 1.7g fiber, 2.3mg iron and 1.6mg zinc. Cooked R5 (100g) had 71.4kcal, 7.1g starch, 2.6g sugars, 4.2g protein, 0.9g fat, 1.0g fiber, 1.9mg iron and 1.4mg zinc. The cooked samples provided more than 50% of the Recommended Nutrient Intake (RNI) for children aged 1-5 years for protein and zinc per serving (200g for children aged 1-3 years and 250g for children aged 4-5 years). Adopting formulations developed in this study can potentially contribute to reducing undernutrition in children aged 1-5 years.

Key words: Low-cost nutrient-dense foods, composite flours, infant feeding, pasting properties, malnutrition

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INTRODUCTION

Globally, the burden of child malnutrition remains a challenge [1]. In 2020, 22% (149.2 million) of children under five years of age were stunted, 6.7% (45.4 million) wasted and 5.7% (38.9 million) overweight. Forty-one percent of the stunted children, 27% of the wasted children and 27% of the overweight children under five were from Africa [2]. Lack of proper nutrition during these early years can have lifelong consequences on educational attainment, health and economic outcomes [3]. The greatest burden of malnutrition is shouldered by children from the poorest and most marginalized communities, perpetuating poverty across generations [1]. In Uganda, 27.9% of children under five are stunted. Furthermore, approximately one-third of households struggle to afford iron-rich foods for children [4].

Malnutrition is caused by the poor quality of children's diets. Forty-four percent of children aged 6 to 23 months worldwide are not fed fruits or vegetables and 59% are not fed eggs, dairy, fish or meat [3]. Fruits and vegetables are rich in micronutrients [5]. Eggs, dairy, fish and meat are good sources of high-quality protein as well as bioavailable iron and zinc [6]. However, poor families are more likely to choose low-cost, low-quality meals [3]. For seasonal crops, the prices vary during the year. Prices peak just before the harvest, when supplies are scarce, and drop substantially immediately after harvest [7]. Consumers make food substitutions based on price variations which has dietary implications and can cause episodes of nutritional deficiencies [8]. There is a global challenge of transforming food systems to ensure that no one is constrained by the high prices of nutritious foods or the lack of income to afford a healthy diet [7].

There is need to develop more nutritious and diverse meals while keeping in mind the resources available, tastes and preferences, and the cost of the eventual diets [9]. Common staples can be blended to enhance the energy and nutrient density of children's diets [9–12]. Using locally available food also assures accessibility, sustainability and affordability [10]. In a previous study in eastern Uganda [13], nine low-cost foods were identified namely sweet potatoes, cooking bananas, cassava, maize, sorghum, soybeans, beans, sesame and groundnuts. However, optimal formulations designed to meet specific nutrient requirements for infant and child feeding were not developed. This study developed acceptable inexpensive and nutritionally adequate flours from locally available foods in Uganda for children aged 1-5 years. These formulations can be adopted and used for child feeding to reduce malnutrition.

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MATERIALS AND METHODS

Materials

Nine low-cost foods (sweet potatoes, cooking bananas, cassava, maize, sorghum, soybeans, beans, sesame and groundnuts) were identified and their nutrient content determined in a previous study in eastern Uganda by Birungi [13]. These food items were purchased from local markets in Pallisa, Kamuli and Buyende districts. Seso and Nambale varieties were considered for sorghum and beans, respectively. For sweet potatoes and groundnuts, the white-fleshed types and red beauty types were considered, respectively.

Collected foods were washed, and dried in an air drier at 60°C for 24 hours [14]. Sweet potatoes, cooking bananas and cassava were thinly sliced to 4mm before drying. The dried foods were stored in airtight containers and kept out of the light.

Formulation of low-cost nutrient-dense composite flour mixtures

Design-Expert® (Version 13) and Nutrisurvey (2007) software were used to generate optimal formulations from the identified foods for the dry and rainy seasons. The target composition of the mixtures and the RNI for the target population are shown in Table 1. According to World Food Program (WFP) [15], 100g of complementary food flours should meet 100% of the Recommended Nutrient Intake (RNI) for nutrients except for energy. Additionally, protein should contribute 6-15% of the total energy [16].

Seven formulations were generated (Table 2). Two of the formulations (D1 and D2) contained foods that were available in the dry seasons while five (R1-R5) contained foods that were more available in the rainy seasons.

Consumer acceptability of the low-cost nutrient-dense formulations

Consumer acceptability of foods developed for young children is evaluated by caregivers, as children are too young to make reasoned decisions regarding food's sensory qualities. Furthermore, it's caregivers who determine which food to offer the child [11]. In this study, 43 students and staff from the School of Food Technology, Nutrition and Bioengineering, Makerere University represented caregivers of children aged 1-5 years.

The formulations were prepared as recommended by WFP [15]. Flour (400g) was mixed with 2000ml of hot water (100°C) in a clean saucepan to make a smooth paste (soup). The soups were cooked for 45 minutes and stored in a thermos flask. The soups (unseasoned) were subjected to sensory evaluation by an untrained panel as described by Lawless & Heymann [17]. The panelists ranked the acceptability for appearance, color, aroma, taste, mouthfeel and overall acceptability of the mixtures using a 9-point hedonic scale (1=dislike extremely to 9=like extremely).

Functional properties
Dispersibility, bulk density, water absorption index (WAI) and water solubility index (WSI) of the most acceptable formulations were determined in triplicate. Dispersibility was determined using the method described by Kulkarni *et al.* [18]. Bulk density was determined using the method described by Wani *et al.* [19]. The WAI and WSI were determined using the method described by Devraj *et al.* [20].

Pasting properties
The pasting properties of the formulations were evaluated using a Rapid Visco Analyser (RVA). The RVA general pasting method was selected.

Color
The color of the formulations was evaluated using a Lovibond® model E Tintometer following the manufacturer's instructions.

Energy and nutrient density
The energy and nutrient density per 100g of the most acceptable cooked formulations were also determined. Moisture content, protein, ash, and crude fat contents were determined using standard Association of Official Analytical Chemists (AOAC) methods [21]. Moisture content was determined using the Air Oven Method, AOAC Method No. 925.10 using an air-forced laboratory oven. Ash was determined using AOAC method 923.03 using a laboratory chamber furnace. Crude fat was determined using the soxhlet method, AOAC Method 922.06 using a Tecator 1043 Soxtec System. Protein content was determined based on the Kjeldahl method, AOAC Method No. 920.87 using a Kjeltec™ 8200 Auto Distillation. A nitrogen-to-protein conversion factor of 6.5 was used [21].

Gross energy was determined by the combustion of a sample in a bomb calorimeter [22]. Sugars and starch were determined using the phenol–sulphuric acid method [23]. Dietary fiber was determined gravimetrically using acid detergent fiber reagent [24]. Iron and zinc were determined using an Atomic Absorption Spectrophotometer [21].

Statistical data analysis

Means and standard deviations for the nutritional, functional, color and sensory properties were derived using IBM® SPSS® Statistics (Version 26). One-way Analysis of Variance (ANOVA) was used to determine the significance of differences among average rankings for the sensory attributes of the formulations. Tukey's test was used to separate means. Independent sample t-tests were used to determine the difference among means generated for color, nutritional and functional properties of two selected formulations. Differences in means were considered statistically significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Consumer acceptability

The mean consumer acceptability scores of the formulations when prepared as recommended by WFP [15] are presented in Table 3. There were no significant differences ($p \leq 0.05$) in the acceptability scores for appearance, color, taste, aroma, mouthfeel and overall acceptability. All formulations were liked with acceptability scores for the different attributes ranging from 6 (like slightly) to 7 (like moderately). Consumers often assess the quality of a food product by its color and appearance [17]. Color also sets expectations about the taste and flavor of the food [25].

Taste and aroma are crucial sensory elements in encouraging children to eat a food. A negative reaction to the taste and aroma of a food can result in rejection by the child [26]. The results indicated that the seven formulations were equally accepted and can be potentially adopted for complementary feeding. Formulations D2 and R5 were considered for the subsequent stages of the study to represent the most acceptable formulations for the dry and rainy seasons, respectively.

Functional properties

The suitability of a food for complementary feeding is influenced by its functional properties, which are a function of product consistency. The consistency of complementary foods supports swallowing and determines the extent to which the growing child can meet their nutrient and energy requirements [12]. The dispersibility, bulk density, WAI and WSI of the most acceptable formulation for dry (D2) and rainy (R5) seasons are presented in Table 4.

Dispersibility is a measure of the reconstitution of flour or flour blends in water [27]. It describes the ease with which flour samples may be distributed as single particles over the surface and throughout the bulk of the constituting water [12].

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There was no significant difference in the dispersibility of D2 and R5 (77.2 and 76.8%, respectively). These values were higher than the values reported by Adebowale *et al.* [27] for fermented cassava paste (69.0-70.3%). They were also higher than the values reported by Anosike *et al.* [12] for complementary foods formulated from maize and African yam bean (66.0-72.0%). Both formulations were easily dispersible (Table 4). Thus, they can be easily reconstituted to give a paste of fine consistency [18] which is preferable for infant foods [6].

Bulk density is the ratio of mass to volume of a flour [19]. The bulk density of D2 and R5 (0.8g/ml) was comparable to the values reported by Tenagashaw *et al.* [28] for composite flour from teff fortified with soybean and orange-fleshed sweet potato (0.7-0.8g/ml). The bulk density reported in this study was, however, lower than the values reported by Anosike *et al.* [12] (0.9 to 1.4g/ml). A low bulk density is preferred in the formulation of complementary foods [6]. Formulations with low bulk densities can be prepared using small amounts of water while still providing the desired nutrient density and consistency. These can easily be fed to children without choking and suffocation [12]. Children can also consume more of the lighter formulations resulting in higher nutrient intake [29].

Water absorption index and water solubility index are a measure of the hydration properties of flour. The WAI is a measure of a flour's capacity to absorb water and swell providing desirable consistency and body to a food system [30]. It determines the volume occupied by the granule or starch polymer after swelling in excess water [31]. D2 had a WAI of 2.0g/g which was significantly higher ($p \leq 0.05$) than that of R5 which was 1.7g/g. This can be attributed to the higher sorghum content of D2. Sorghum has been reported to have a WAI of 4.54g/g [32]. The values reported in this study were lower than the values reported by Tenagashaw *et al.* [28] (2.2 to 4.9g/g). They were also lower than the values reported by Adeola *et al.* [33] for complementary foods from blends of sorghum, pigeon pea, and soybean flour (2.0-3.0g/g). Flour with a low WAI forms thinner gruels to which more flour can be added per unit volume. This results in nutrient-dense gruels [28] that are desirable for complementary feeding [6].

Water solubility index determines the amount of polysaccharides released from the granule on the addition of excess water. High WSI is an indicator of good starch digestibility [31]. R5 had a WSI of 0.3g/g which was significantly higher ($p \leq 0.05$) than that of D2 which was 0.2g/g. This can be attributed to the higher groundnut content of R5. Salve & Arya [34] reported that groundnuts have a WSI of 0.35g/g. The values in this study were higher than the values reported by Tenagashaw *et al.* [28] (0.08-0.16g/g). They were also higher than the values reported by Adeola *et al.* [33] (0.04-0.05g/g). The water solubility index of D2 was comparable to 0.2g/g reported by Mahgoub *et al.* [35] for instant porridge supplemented with mung bean but the WSI of R5 was higher. The higher WSI of the formulations suggests that they are easier to digest [31] and are as such desirable for complementary feeding.

Pasting properties
The pasting properties of the two most acceptable formulations (D2 and R5) are presented in Table 5. There was no significant difference (p>0.05) in the peak and breakdown viscosities of D2 and R5. However, D2 had significantly (p≤0.05) higher tough, final and setback viscosities. The significant differences in the trough, final and breakdown viscosities can be attributed to the difference in components of D2 and R5. D2 contained more sorghum, soybean and sesame than R5. Sorghum has been reported to have high trough, final and setback viscosities of 108.5, 218.67 and 110.21 RVU, respectively [36]. Agume *et al.* [37] reported that soybean has high trough and final viscosities of 91 and 103 RVU respectively. Sesame also has high trough and final viscosities of 125.5 and 120.5 RVU, respectively [38].

The peak, trough, breakdown, final and setback viscosities reported in this study (60.3, 56.7, 3.7, 100.7 and 44.0 RVU, respectively for D2 and 55.3, 49.0, 6.3, 86.3 and 37.3 RVU, respectively for R5) were lower than 235, 127, 108, 183 and 74 RVU, respectively as reported by Anosike *et al.* [12]. The peak, trough, breakdown, final and setback viscosity values in this study were also lower than 268, 247, 21, 406 and 159 RVU, respectively as reported by Onwurafor *et al.* [39] for complementary foods formulated from sorghum, maize and mung bean. Flours with low peak viscosity and low final viscosity are desirable for complementary feeding as they form less viscous nutrient-dense pastes [12]. Trough viscosity and breakdown viscosity are a measure of paste stability. A low trough viscosity and breakdown viscosity indicate higher paste stability at high temperatures and shear during cooking [29].

Setback viscosity is a measure of the retrogradation tendency of the paste on cooling [19]. The low setback viscosities of D2 and R5 imply the formulations have a high resistance to retrogradation on cooling [19]. Retrogradation causes an increase in viscosity [30] which is undesirable in complementary food. The significantly lower trough viscosity, final viscosity and setback viscosity however imply that R5 will form a less viscous and more stable paste that is more resistant to retrogradation. This makes R5 more suitable for complementary feeding.

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Peak time is the time taken to reach peak viscosity [30]. It is a measure of cooking time. A higher peak time implies a longer cooking time [27]. The peak times in this study (6.6-6.8 minutes) were higher than the peak times reported by Anosike *et al.* [12] (6.09-6.35 minutes). They were also higher than the 5.13 minutes reported by Onwurafor *et al.* [39]. D2 and R5 will thus take longer to cook.

Peak temperature is the temperature at which the sample attains peak viscosity. It is a measure of the minimum temperature required to cook a sample [39]. The pasting temperature of D2 (78.7^{o}C) and R5 (78.3^{o}C) were lower than the values reported by Anosike *et al.* [12] (90-92^{o}C) and Onwurafor *et al.* [39] (81.1- 89.6^{o}C) implying a lower cooking temperature.

Color

The color of a food sets the expectation about the taste and flavor, making it the most important product-intrinsic sensory cue [25]. The color properties of the most acceptable formulations are presented in Figure 1. There was no significant difference in the red, yellow, blue and sample brightness readings for D2 and R5 ($p>0.05$). The composite flours generally had a color described as yellow-green based on the Lovibond® RYBN color scale. There were no significant differences in the color properties implying that the differences in formulations did not impact the overall color of the composite flours developed. This could be attributed to the fact that although D2 and R5 were different formulations, the main components of both were sesame, groundnuts and sorghum. They both contained beans as well. The similarity in color readings also explains why there was no significant difference in acceptability for color (Table 3).

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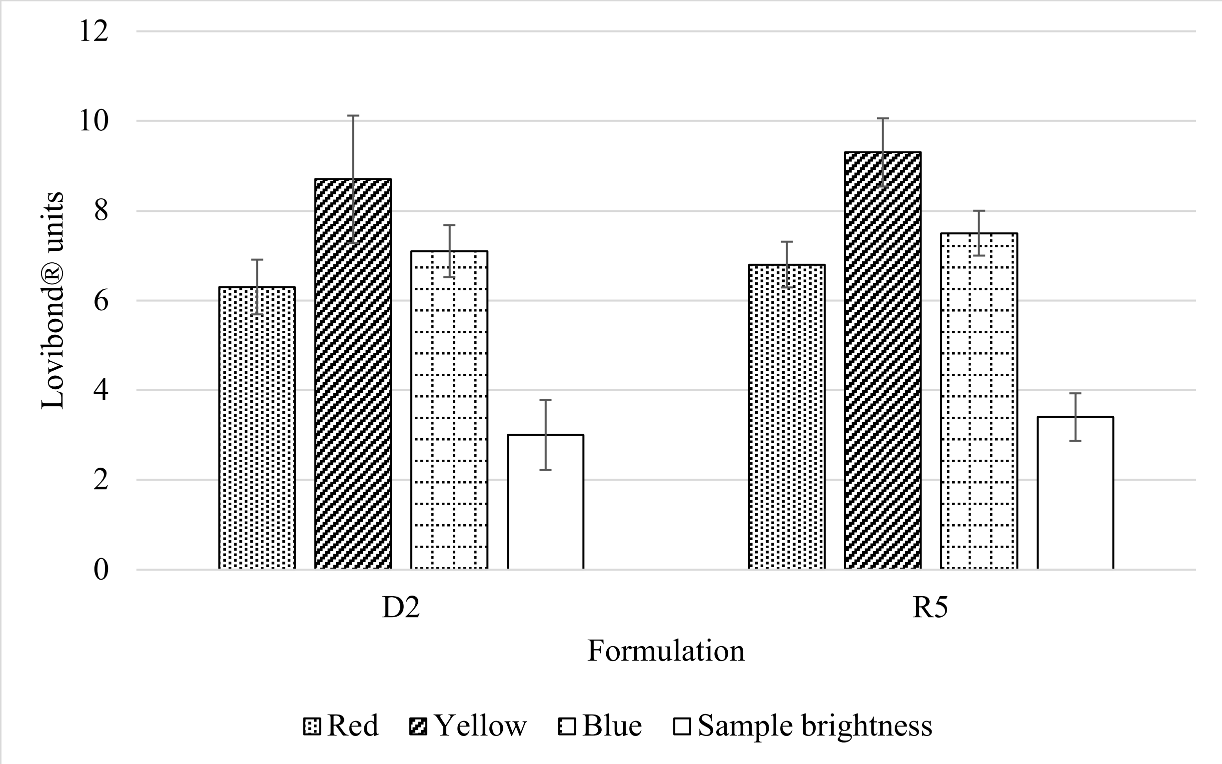

Figure 1: Color properties of the most acceptable formulations

Young children are drawn to brightly colored foods [25]. Both D2 and R5 were bright samples suggesting that they could be desirable to children. The color of D2 and R5 were acceptable to the sensory panellists (Table 3).

Nutrient density

Table 6 shows the energy and nutrients provided by 100g of cooked D2 and R5 when prepared according to WFP [15] instructions. D2 had 87.2kcal of energy, 2.3g of sugar, 9.5g of starch, 5.8g of protein, 1.6g of crude fat, 1.7g of fiber, 0.8g of ash, 2.3mg of iron and 1.6mg of zinc per 100g. R5 had 71.4kcal of energy, 2.6g of sugar, 7.1g of starch, 4.2g of protein, 0.9g of crude fat, 1.0g of fiber, 0.6g of ash, 1.9mg of iron and 1.4mg of zinc per 100g. There was no significant difference in the energy, moisture, protein, fiber, iron and zinc compositions of D2 and R5. However, there was a significant difference in the sugar, starch, crude fat and ash compositions. The differences can be attributed to the difference in foods used in the formulations (Table 2). The higher sugar content of R5 can be attributed to the higher quantity of beans and groundnuts in R5 which have higher sugar contents. R5 also had a higher starch content than D2 and this can be attributed to the inclusion of maize in formulation R5 as well as the higher quantity of beans. The higher crude fat and ash content of D2 can be attributed to the higher quantity of sesame in D2 as sesame has higher crude fat and ash content compared to all the other foods that were used in the formulations.

The World Health Organization [6] recommends that the energy density of a complementary food be at least 0.67kcal/g and closer to 1kcal/g (67-100kcal/100g). Both D2 and R5 met the minimum energy density (Table 6). The energy content of the formulations can be brought closer to 1kcal/g by addition of energy-containing ingredients such as fats and oils or digestible carbohydrates [16].

The percentage contribution of the cooked formulations to daily RNI of energy, protein, iron and zinc for children aged 1-5 years is presented in Figure 2. The serving sizes considered were 200g for children aged 1-3 years and 250g for children aged 4-5 years based on UNICEF [40] recommendations. There were significant differences in the energy contributions of the cooked formulations to the daily energy RNI and no significant differences in the protein, iron and zinc contributions to the daily RNI of children aged 1-5 years. This can be attributed to the significantly lower sugar, starch and crude fat contents of R5 as these are the major sources of energy [16].

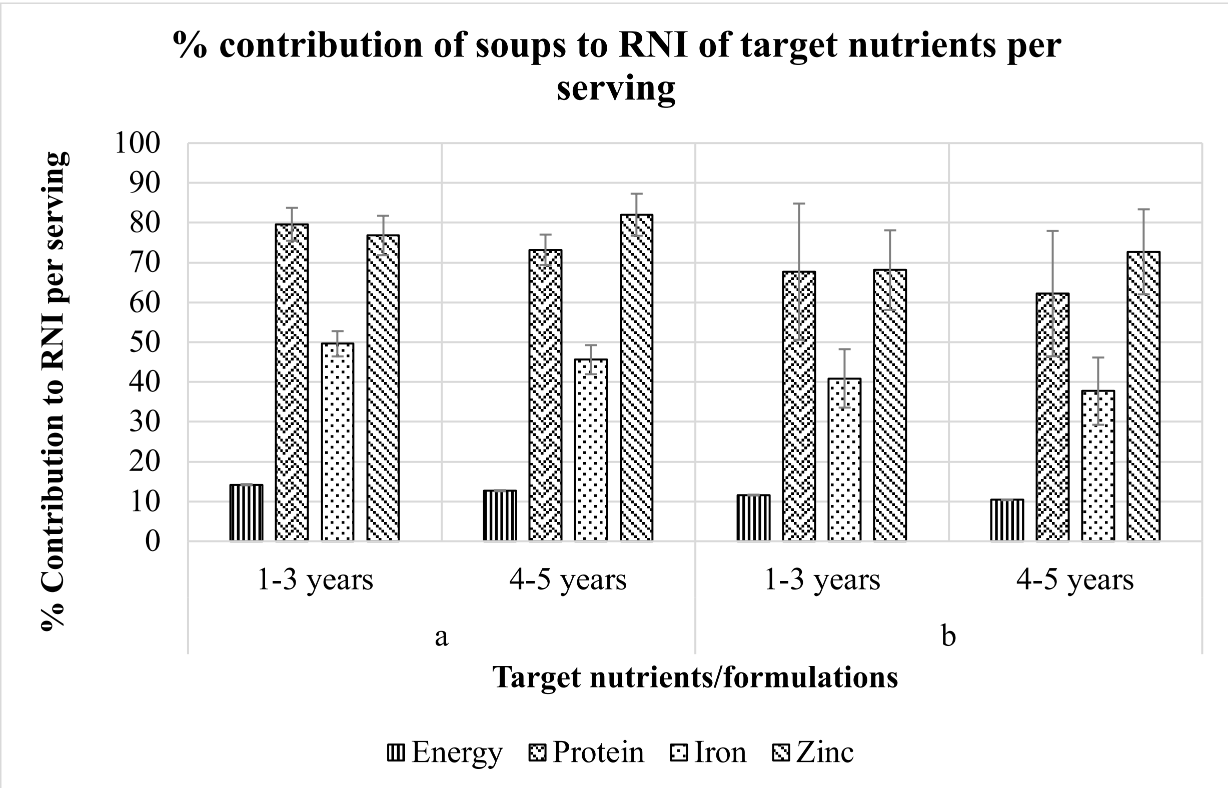

Figure 2: Percentage contribution of cooked composite flours to target nutrients per serving. a is the soup prepared from D2, b is the soup prepared from R5

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The minimum requirement of a complementary food is to meet at least 50% of the RNI for most nutrients except energy per serving [6,15]. For children aged 1-3 years, the RNI for protein is 14.5g/day, iron 11.6mg/day and zinc 4.2 mg/day. For children aged 4-5 years, the RNI for protein is 19.7g/day, iron 12.6mg/day and zinc 4.8mg/day. The protein and zinc contents of both D2 and R5 met more than 50% of the RNI for children aged 1-5 years (Figure 2). The iron contents of both D2 and R5 however did not meet 50% of the RNI for children aged 1-5 years. The iron content of the formulations can be improved by fortification of the flour [15].

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Low-cost and available foods such as sweet potatoes, maize, sorghum, soybeans, beans, sesame and groundnuts can be used to develop nutrient-dense composite flours for complementary feeding. The formulations developed in this study are acceptable and can meet the minimum recommended energy density and more than 50% of the recommended RNI for protein and zinc for children aged 1-5 years when prepared according to the WFP instructions. These formulations can be adopted by caretakers of children aged 1-5 years to reduce undernutrition by providing low-cost nutritious options. Further studies should investigate the *in vitro* digestibility and mineral bioavailability of the composite flours in order to predict the fraction of nutrients that would be absorbed by a child`s gastrointestinal tract. These formulations, however, cannot be solely relied on to provide all the nutrient requirements of the children, as they might be deficient in vitamins and some minerals. The consumption of fruits and vegetables along with these formulations should also be promoted.

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Table 1: Target nutrient content per 100g of flour

Nutrient content per 100g of flour	Target	RNI for children aged 1-3 years per day	RNI for children aged 4-5 years per day
Energy (kcal)	525 (6-15% from protein)	1,230	1,715
Protein (g)	19.7	14.5	19.7
Iron (mg)	12.6	11.6	12.6
Zinc (mg)	4.8	4.1	4.8

Sources: [5,6]

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Table 2: Optimal formulations generated by Design-Expert®

Formulation /Season	Components in the formulation per 100g							Target/Estimated* nutrient content per 100g			
	Sweet potatoes (g)	Maize (g)	Sorghum (g)	Soybeans (g)	Beans (g)	Sesame (g)	Groundnuts (g)	Energy (kcal)	Protein (g)	Iron (mg)	Zinc (mg)
Recommendation [15]								525	19.7	12.6	4.8
Dry seasons											
D1	0.47	2.18	-	-	30.57	34.63	32.16	660.5	22.58	5.96	4.26
D2	-	0.00	25.35	1.31	4.34	33.11	35.89	660.2	20.25	6.02	4.20
Rainy seasons											
R1	-	13.48	8.66	-	10.51	28.72	38.63	655.6	20.81	5.55	4.23
R2	-	16.29	9.65	-	6.39	29.00	38.67	656.4	20.30	5.43	4.23
R3	-	20.46	8.10	-	3.94	28.93	38.57	656.3	19.94	5.27	4.23
R4	-	18.65	13.25	-	0.00	29.18	38.91	656.8	19.53	5.32	4.23
R5	-	4.95	20.98	-	5.49	29.39	39.19	656.2	20.35	5.85	4.21

*Nutrient content of the formulations was estimated using Nutrisurvey and the nutrient contents of the ingredients obtained from a previous study on the nutritional composition of least-cost sources of nutrients in eastern Uganda. The symbol (-) indicates that a food was not used in the formulation

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Table 3: Consumer acceptability of developed formulations

Formulation		Acceptability Scores of Different Sensory Attributes					
Season	**Identifier**	**Appearance**	**Color**	**Taste**	**Aroma**	**Mouthfeel**	**Overall acceptability**
Dry	D1	7 ± 1[ab]	7 ± 1[ab]	6 ± 2[a]	7 ± 1[a]	6 ± 1[a]	6 ± 1[a]
Dry	D2	7 ± 1 [ab]	7 ± 1[b]	6 ± 2[a]	6 ± 2[a]	6 ± 2[a]	6 ± 2[a]
Rainy	R1	7 ± 1[ab]	7 ± 1[ab]	6 ± 2[a]	6 ± 2[a]	6 ± 2[a]	7 ±1[a]
Rainy	R2	6 ± 2[a]	6 ± 1[a]	6 ± 2[a]	6 ± 2[a]	6 ± 2[a]	6 ± 1[a]
Rainy	R3	7 ± 1[b]	7 ± 1[b]	6 ± 2[a]	6 ± 1[a]	6 ± 2[a]	7 ± 1[a]
Rainy	R4	7 ± 1[ab]	7 ± 1[b]	6 ± 2[a]	6 ± 1[a]	6 ± 2[a]	7 ± 2[a]
Rainy	R5	7 ± 1[b]	7 ± 1[b]	6 ± 2[a]	6 ± 2[a]	6 ± 2[a]	7 ± 1[a]

Values are means ± standard deviation (n=43). Means in each column with different superscripts are significantly different (p≤0.05)

Table 4: Functional properties of D2 and R5

Formulation	Dispersibility (%)	Bulk density (g/ml)	WAI (g/g)	WSI (g/g)
D2	77.2 ± 0.67[a]	0.8 ± 0.06[a]	2.0 ± 0.06[a]	0.2 ± 0.03[a]
R5	76.8 ± 1.15[a]	0.8 ± 0.05[a]	1.7 ± 0.01[b]	0.3 ± 0.00[b]

Values are means ± standard deviation of triplicate determinations. Means in each column with different superscripts are significantly different (p≤0.05)

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Table 5: Pasting properties of D2 and R5

Formulation	Peak viscosity (RVU)	Peak Time (Minutes)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Pasting Temperature (°C)
D2	60.3 ± 1.15[a]	6.8 ± 0.21[a]	56.7 ± 0.58[a]	3.7 ± 0.58[a]	100.7 ± 2.31[a]	44.0 ± 1.73[a]	78.7 ± 0.58[a]
R5	55.3 ± 4.51[a]	6.6 ± 0.41[a]	49.0 ± 1.73[b]	6.3 ± 3.21[a]	86.3 ± 0.58[b]	37.3 ± 1.53[b]	78.3 ± 0.58[a]

Values are means ± standard deviation of triplicate determinations. Means in each column with different superscripts are significantly different (p≤0.05) RVU=Rapid Visco Units

Table 6: Energy and nutrient density per 100g of cooked D2 and R5

Formulation	Energy (kcal)	Moisture (g)	Sugars (g)	Starch (g)	Protein (g)	Crude fat (g)	Fiber (g)	Ash (g)	Iron (mg)	Zinc (mg)
D2	87.2 ± 0.94[a]	76.3 ± 1.85[a]	2.3 ± 0.01[a]	9.5 ± 0.11[a]	5.8 ± 0.30[a]	1.6 ± 0.15[a]	1.7 ± 0.34[a]	0.8 ± 0.01[a]	2.3 ± 0.18[a]	1.6 ± 0.10[a]
R5	71.4 ± 0.64[a]	80.1 ± 0.04[a]	2.6 ± 0.04[b]	7.1 ± 0.48[b]	4.2 ± 0.40[a]	0.9 ± 0.05[b]	1.0 ± 0.00[a]	0.6 ± 0.02[b]	1.9 ± 0.43[a]	1.4 ± 0.21[a]

Values are means ± standard deviation of triplicate determinations. Means in each column with different superscripts are significantly different (p≤0.05)

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