Amaranth leaf powder and skinned milk improve the nutritional, functional, rheological and sensory properties of orange fleshed sweet potato flour

Gaston A. Tumuhimbise1,*; Gerald Tumwine1; William Kyamuhangire1

1 School of Food Technology, Nutrition and Bioengineering, College of Agricultural and Environmental Sciences, Makerere University, P.O Box 7062 Kampala, Uganda

* Correspondence: ampston23@gmail.com

Abstract: Vitamin A deficiency (VAD) and under nutrition are major public health concerns in developing countries. Diets with high vitamin A and animal protein can help reduce the problem of VAD and under nutrition respectively. In this study, composite flours were developed from orange fleshed sweet potato (OFSP), amaranth leaves and skinned milk powders; 78:2:20, 72.5:2.5:25, 65:5:30 and 55:10:35. The physical-chemical characteristics of the composite flours were determined using standard methods while sensory acceptability of porridges was rated on a nine-point hedonic scale using a trained panel. Results indicated a significant \((p < 0.05)\) increase in protein (12.1 to 19.9%), iron (4.8 to 97.4 mg/100 g) and calcium (45.5 to 670.2 mg/100 g) contents of the OFSP-based composite flours. The vitamin A content of composite flours contributed 32 to 442% to the recommended dietary allowance of children 6-59 months. The composite flours showed a significant \((p \leq 0.05)\) decrease in solubility, swelling power and scores of porridge attributes with increase in substitution levels of skinned milk and amaranth leaf powder. The study findings indicate that the OFSP-based composite flours have the potential to make significant contribution to the improvement in the nutrition status of children 6-59 months in developing countries.

Keywords: Functional properties; orange fleshed sweet potato; vitamin A; porridge; skinned milk

1. Introduction

Under nutrition affects millions of people globally with high proportions in the developing countries [1]. Micronutrient deficiencies such as vitamin A and iron deficiencies are the major public health concerns in resource poor communities [2,3]. In many developing countries, many programs have been implemented to reduce vitamin A and iron deficiencies. One of the programs that has been implemented to reduce vitamin A and iron deficiencies is the use of bio-fortified sweet potatoes such as orange fleshed sweet potatoes (OFSP) and beans respectively [4,5]. In addition, industrial food fortification has also been used to add essential micronutrients such as iron, zinc, vitamin B complex and vitamin A to foods [6]. Despite all the interventions, under nutrition in most developing countries remains a challenge. The persistent high levels of macro and micronutrient deficiencies in developing countries are attributed to the dependence on plant based foods. Plant based foods are relatively cheaper and can be afforded by most households. On the other hand, plant based foods have relatively lower protein quality and limited bioavailability. Inadequate intake of quality protein and micronutrients such as iron and vitamin A [3] might have contributed to the widespread of macro and micronutrient malnutrition manifested in children 6-59 months [1]. In order to reduce vitamin A deficiency in developing countries, orange fleshed sweet potatoes are used in formulation of complementary diets due to high content of naturally bio-available \(\beta\)-carotene [7,8]. Studies have indicated that orange fleshed sweet potato (OFSP) flour is rich in \(\beta\)-carotene \((100-1600 \, \text{mg} \, \text{RAE/100})\).
g for varieties in Africa)\cite{9, 10}, energy (293 to 460 kJ/100 g) \cite{11} and significant amounts of iron, zinc and manganese \cite{12}. Although orange fleshed sweet potato and its products may have many positive attributes and cheaper than other crops, it is limited in other micronutrients such as calcium, sodium, potassium and phosphorus and quality proteins \cite{13}. Therefore, orange fleshed sweet potato alone cannot be used to combat the different types of nutrient deficiencies afflicting the vulnerable communities in developing countries. Thus there is a need to enhance the macro and micronutrient profile of OFSP using locally available foods. Green leafy vegetables such as amaranth have also been documented to contain essential micronutrients and proteins \cite{14}.

Amaranth leaves are considered as one of the principle leafy vegetables in tropical areas with high annual production \cite{15}. However, they are mainly used as salads and sauces by adults in most areas \cite{16, 17}. Amaranth leaves are rich in β-carotene, vitamin C, iron, calcium and zinc \cite{18}. On the other hand skinned milk powder is the excellent source of proteins (34 to 37%), rich in calcium (1,257 mg/100 g) \cite{19}. Milk protein is the source of all the essential amino acids with high protein digestibility \cite{20}. Addition of skinned milk and amaranth leaves powder to orange fleshed sweet potato flour could be a better option to provide better overall essential amino acid balance and micronutrients. This could help to overcome the global protein calorie and micronutrient malnutrition challenges respectively. The aim of this study was therefore to develop a nutrient enhanced orange fleshed sweet potato-based composite flour incorporating skinned milk and amaranth leaf powders suitable for children 6-59 months.

2. Materials and Methods

2.1. Source of raw materials and laboratory reagents

Orange fleshed sweet potatoes (NASPOT 13 variety, maturity; 5 months) and amaranth leaves were obtained from National Crop Resources Research Institute (NaCRII), Namulonge, Uganda. Skimmed milk powder was purchased from Pearl Dairies, Mbarara District, Uganda. All the materials were delivered to the laboratory at the School of Food Technology, Nutrition and Bioengineering, Makerere University for further processing. Laboratory reagents were purchased from Neo Faraday Laboratory Supply, Kampala, Uganda.

2.2. Preparation of OFSP flour

The OFSP roots (NASPOT 13 variety, maturity; 5 months) were washed, peeled and cut into thin pieces manually using a hand grater with holes of a diameter of 0.6 cm, spread on solar drier trays and dried for 24 h. The dry OFSP was milled into fine powders using a locally fabricated hammer mill. The OFSP and composite flours were packaged in aluminium packages and stored in the freezer before they were used. OFSP acted as a control.

2.3. Preparation of amaranth leaves

Amaranth leaves were washed with potable water to remove surface soil. The amaranth leaves were dipped in 5% saline solution for 15 min. After 15 min, amaranth leaves were dried for 24 h in a locally made solar drier. Dried amaranth leaves were then milled into fine powder using a locally fabricated hammer mill.

2.4. Composite flour preparation

The five different combinations of orange fleshed sweet potato, amaranth leaves and skimmed milk powders (Table 1) were used in the composite flour. The selection of proportions of each ingredient used in composite flour was based on published findings \cite{21}. Orange fleshed sweet potato flour was blended with amaranth leaves and skinned milk powder by using a mixer (Lilaram Manomal and Sons, India). The composite flour samples were packaged in aluminium packages and stored in plastic buckets at room temperature.
Table 1. Different proportions of OFSP, amaranth leaves and skimmed milk powders used in composite flour.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>OFSP flour</th>
<th>Amaranth leaves powder</th>
<th>Skimmed milk powders</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GT1</td>
<td>78.0</td>
<td>2.0</td>
<td>20.0</td>
</tr>
<tr>
<td>GT2</td>
<td>72.5</td>
<td>2.5</td>
<td>25.0</td>
</tr>
<tr>
<td>GT3</td>
<td>65.0</td>
<td>5.0</td>
<td>30.0</td>
</tr>
<tr>
<td>GT4</td>
<td>55.0</td>
<td>10.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>

2.5 Nutrient composition of OFSP-based composite flours

2.5.1. Proximate composition and energy estimation

The OFSP and OFSP-based composite flours were analyzed for moisture, crude protein, crude fat, crude fiber and ash contents according using a method already published[22]. The carbohydrate component was determined by difference and energy content was determined by using the Atwater factor (carbohydrate and protein values were each multiplied by 4 kcal/g, whereas fat values were each multiplied by 9 kcal/g).

2.5.2. Determination of minerals

The amount of calcium, zinc, iron and phosphorus in the composite flours was measured by an atomic absorption spectrophotometer (AAS) [23]. Calibration equations were derived and concentrations of calcium, zinc, iron and phosphorus were expressed as mg/100 g.

2.5.3. Determination of vitamin A (RAE)

The vitamin A (RAE) content of flours was determined according to a method described by [24]. Carotenoid and the vitamin A (RAE) contents were expressed as µg/g and µg RAE respectively.

2.6 Determination of physical properties of millet-based composite flour

The bulk density, water and oil absorption capacities of the millet flours were determined methods already documented[25].
2.7. Determination of swelling capacity and solubility of millet based composite flour

The swelling power and solubility of the sample were determined using a method already described by other researchers [26]. The swelling power and solubility of the samples were expressed as:

\[ \text{Swelling power(\%)} = \frac{\text{weight of sediment paste (g)} \times 100}{\text{weight of sample (g)} \times (100 - \% \text{Solubility})} \]

\[ \text{Solubility(\%)} = \frac{\text{weight of soluble starch (g)} \times 100}{\text{weight of sample (g)}} \]

2.8. Pasting properties

Pasting characteristics of the porridge from the composite flours were determined with a Rapid Visco Analyzer (Perten Instruments AB, Kungens Kurva, Sweden) according to [27]. Peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperatures were read from the pasting profile with the aid of thermocline for windows software connected to a computer [28]. The viscosity was expressed in centipoises (cP).

2.11. Contribution of porridge from composite flours to RDA

Percentage contribution to recommended dietary allowance was expressed as % of RDA.

\[ \% \text{RDA} = \frac{X}{Y} \times 100 \]

Where X is the amount of nutrient analyzed and Y is the RDA for a given nutrient/variable.

2.12. Sensory evaluation of composite flour porridges

Porridges were prepared by adding separately 200 g of OFSP and OFSP-based composite flours in 250 ml of cold water. The resulting paste was added to 550 ml of boiling water and cooked for 15 min with constant stirring. The prepared porridge was kept in coded thermos vacuum flasks. The sensory attributes of porridges were evaluated by thirty (30) trained panelists comprising of students and staff in the School of Food Technology, Nutrition and Bio-Engineering-Makerere University. The ages of panelist ranged from 18 to 45 years and there were 16 females and 14 male. Each panelist sat in an individual booth and was provided with hot porridge samples in plastic disposable cups marked with 3-digit random codes. Each panelist was provided with drinking water to rinse the palate after each taste. The sensory attributes of porridges that were evaluated included; colour, taste, aroma, aftertaste, and overall acceptability. The attributes were rated on a nine-point hedonic scale (like extremely = 9 to dislike extremely = 1).

2.13. Statistical analysis

All experimental determinations were carried out in duplicates and subjected to statistical Analysis of Variance (ANOVA) using XLSTAT software version 2017 to determine variation between means. Significance variation was accepted at p < 0.05. Experimental results were expressed as the means ± standard deviations.

3. Results and discussion

3.1. Proximate and energy composition of orange fleshed sweet potato-based composite flours

The moisture, ash, protein, fat, carbohydrate, fibre and energy contents of orange fleshed sweet potato-based composite flours on dry weight basis are presented in Table 2. The moisture content of
OFSP and OFSP-based composite flours ranged from 5.4% to 5.9%. The moisture content was insignificantly (p>0.05) highest in GT4 and lowest in GT3. The moisture content of OFSP and composite flours was slightly higher than the moisture content (≤ 5%) recommended by codex standards for complementary foods. On the other hand, a moisture content ranging from 6.9 to 10.9% in different varieties of OFSP flours has been reported before [29]. The low moisture content of the flours is attributed to proper drying and handling. The low moisture content of the flours is therefore important in maintaining stable storage over long periods. The carbohydrate content of flours significantly (p < 0.05) decreased from 86.0 to 67.8%. The decrease in carbohydrate content is attributed to the dilution effect of skimmed milk (49.5-52.0%) [30] and amaranth leaf powders (28.2%) [31], which are low in total carbohydrates. However, another study reported carbohydrate content of sweet potato, skimmed milk powder and maize based complementary foods in the range 50.25 to 58.92% [32], which are lower than those reported in this study. Similar trend (64.8 to 57.1%) was also reported by [33] with addition of amaranth leaves powder in yellow maize flour at 20% substitution level.

Table 2. Proximate (%) and energy (kcal/100 g) composition of orange fleshed sweet potato-based composite flours on dry weight basis (except moisture content):

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture content</th>
<th>Ash</th>
<th>Crude protein</th>
<th>Crude fat</th>
<th>Total carbohydrates</th>
<th>Crude fibre</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP</td>
<td>5.8±0.2</td>
<td>2.7±0.0</td>
<td>4.1±0.3</td>
<td>0.4±0.1</td>
<td>86.0±0.3</td>
<td>1.2±0.4</td>
<td>389ab±0.0</td>
</tr>
<tr>
<td>GT1</td>
<td>5.7±0.2</td>
<td>4.0±0.3</td>
<td>12.1±0.5</td>
<td>0.7±0.0</td>
<td>76.7ab±0.8</td>
<td>1.5b±0.0</td>
<td>387ab±0.1</td>
</tr>
<tr>
<td>GT2</td>
<td>5.7±0.3</td>
<td>4.3±0.1</td>
<td>13.9±0.4</td>
<td>1.1±0.4</td>
<td>73.6±0.5</td>
<td>2.2±0.3</td>
<td>386ab±0.0</td>
</tr>
<tr>
<td>GT3</td>
<td>5.4±0.6</td>
<td>4.6b±0.2</td>
<td>17.0a±0.6</td>
<td>1.1ab±0.1</td>
<td>71.6c±1.6</td>
<td>2.5b±0.0</td>
<td>383b±0.0</td>
</tr>
<tr>
<td>GT4</td>
<td>5.9±0.7</td>
<td>5.3±0.2</td>
<td>19.9±0.4</td>
<td>1.4±0.4</td>
<td>67.8d±0.0</td>
<td>3.2b±0.4</td>
<td>379b±0.0</td>
</tr>
</tbody>
</table>

p-value 0.694 <0.0001 <0.0001 0.122 <0.0001 0.062 0.283

Values in the Table are means ± standard deviations of duplicate determinations. Means in the same column with different superscripts are significantly (p<0.05) different. Samples GT1, GT2, GT3 and GT4 are orange fleshed sweet potato-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively.

The was no significant decrease (p > 0.05) in the energy content of flours. The slight decrease in energy content observed in this study is attributed to the decrease in carbohydrates (Table 2) due to addition of skimmed milk and amaranth leaf powders. This is because energy is strongly correlated to dry matter and moisture content [34]. Findings in this study indicated a higher energy content compared to 350 - 360 kcal/100 g reported by [33] in yellow maize flour supplemented with 20% amaranth leaf powder. The energy content of OFSP based composite flours is approximately half the total energy required for healthy breastfed infants; 615 kcal/day from 6 to 8 months of life, 686 kcal/day from 9 to 11 months and 894 kcal/day from 12 to 23 months [35,36]. Therefore, the OFSP based composite flours can be used in making complementary porridges for children aged 6-59 months.

Study findings further indicated that addition of skimmed milk and amaranth leaf powder significantly increased the ash content of OFSP flour from 2.7 to 5.3%. The increase in ash content was highest in GT4 and lowest in GT1. The significant increase in the ash content in OFSP-based composite flours is attributed to addition of amaranth leaf powders because they are reported to be rich in minerals (10.6% ash) as previously reported [31]. Findings in this study are in agreement with those of another study that reported an increase in ash content of yellow maize flour from 1.3 to 4.6% with addition of 20% amaranth leaf powder [33].

The protein content of OFSP-based composite flours significantly (P<0.05) increased from 4.1 to 19.9%. The protein content for GT1 and GT2 were lower while those of GT3 and GT4 were higher
than that of the protein value (15%) stipulated in the Codex standard of complementary foods. Therefore, GT3 and GT4 comply with the permitted levels (15%) of formulated complementary foods [37]. This observation could be due to the fact that blending of two or more plant and animal-based food materials increases the nutrient density of the food product [38]. The increase in protein content of OFSP-based composite flours is also attributed to addition of skimmed milk (34-37% protein) and amaranth leaves (32.5% protein). Other studies have reported an increase in the protein content (17.9%) of a complementary food formulated from rice, fib beans, sweet potato flour, and peanut oil [39].

The fat content of OFSP flour significantly (p=0.122) increased from 0.4 to 1.4%. The fat content was highest in GT4 and lowest in OFSP flour (control). The increase in fat content is attributed to increase in levels of skimmed milk powder added to OFSP flour. The low fat content of OFSP-based composite flours is better for longer storage of the flours if properly packaged and stored in areas with low humidity and temperature. Findings from this study showed lower fat content (0.7 to 1.4%) than that (3.87 to 5.17%) reported by [40] in flat-bread prepared from blends of maize and OFSP flours. This is because maize flour has higher fat content (6.95%) [40] than skimmed milk powder (1.5%) [41].

The crude fibre content of OFSP-based composite flours increased from 1.2 to 3.2%. A significant increase in crude fibre content was observed between GT2 and other samples. This is attributed to higher amaranth leaves powder added to OFSP flour because amaranth leaf powder is reported to have higher fibre content (18.11%) [31] than OFSP (2.57%) [29]. Findings from this study are in agreement with other studies that reported an increase in the crude fibre content of extruded provitamin A biofortified maize snacks with addition of 1 and 3% amaranth leaf powder [31]. The crude fibre content of the OFSP-based composite flours was within the recommended Codex Standards (5%) for complementary foods. Therefore, the composite flours are suitable for use in complementary feeding of children 6-59 months.

### 3.2. Mineral and vitamin A (µg RAE) content of orange fleshed sweet potato-based composite flours

The results for mineral and vitamin A (µg RAE) content of orange fleshed sweet potato-based composite flours are presented in Table 3. The vitamin A (µg RAE) content of OFSP and OFSP-based composite flours decreased from 1989.8 to 145.7 µg RAE/100 g with increase in the substitution levels of amaranth leaves and skimmed milk powders. The decrease in vitamin A (µg RAE) content of OFSP flour was significantly (P<0.05) different from that of OFSP-based composite flours. The decrease in the vitamin A (µg RAE) content of OFSP-based composite flours is attributed to the dilution effect due to addition of skimmed milk that has low levels of vitamin A (µg RAE). Findings from this study showed that vitamin A concentrations are higher (226.24 µg RAE/100 g) than that reported in Orange-fleshed sweet potato-based infant food [32]. In addition, [42] reported 1924 µg RE/100 g in orange fleshed sweet potato flour which was slightly lower than that from this study. The differences in vitamin A (RAE) are attributed to drying temperatures and period.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Vitamin A (µg RAE/100 g)</th>
<th>Fe (mg/100 g)</th>
<th>Ca (mg/100 g)</th>
<th>P (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP flour</td>
<td>1989.8±1.2</td>
<td>4.8±0.4</td>
<td>45.5±0.4</td>
<td>69.2±0.2</td>
</tr>
<tr>
<td>GT1</td>
<td>1447.3±1.1</td>
<td>19.6±0.6</td>
<td>321.2±0.2</td>
<td>253.7±0.2</td>
</tr>
<tr>
<td>GT2</td>
<td>563.8±0.4</td>
<td>24.5±0.1</td>
<td>394.3±0.4</td>
<td>299.4±0.9</td>
</tr>
<tr>
<td>GT3</td>
<td>343.9±0.2</td>
<td>48.8±0.1</td>
<td>506.2±0.1</td>
<td>345.2±0.4</td>
</tr>
<tr>
<td>GT4</td>
<td>145.7±1.4</td>
<td>97.4±0.2</td>
<td>670.2±0.3</td>
<td>388.3±0.4</td>
</tr>
</tbody>
</table>

Table 3. Mineral and vitamin A (µg RAE) content of orange fleshed sweet potato-based composite flours on dry weight basis.
Study findings also indicated a significant (P<0.05) increase in iron (4.8 to 97.4mg/100 g), calcium (45.5 to 670.2 mg/100 g) and phosphorus (69.2 to 388.3 mg/100 g). The increase in iron, calcium and phosphorus content of OFSP-based composite flours is attributed to the addition of amaranth leaves powder because they are reported to be in these minerals [31]. In addition, the reported high calcium content is attributed to addition of skimmed milk powder (1257 mg/100 g) [30].

### 3.3. Contribution of energy and protein content of porridge prepared from 200 g of OFSP-based composite flours in 800 ml of water towards RDA for children aged 6-59 months

Table 4 shows the contribution of OFSP-based composite flours to the RDAs of energy and protein for children aged 6-59 months. The study findings indicated that the protein contribution to the RDA reduced with an increase in the age of children. For children 0.5 – 1 year, the porridge from OFSP-based composite flours contributes 86.4 to 142.1% of the RDA for protein but it contributes only 50.4 to 82.9% for children aged 4-6 years. Energy contribution was 45.5 to 44.6% for children 0.5-1 year and 21.5 to 21.1% for children 4-6 years (Table 4).

<table>
<thead>
<tr>
<th>Variable (kcal/day)</th>
<th>Age group (years)</th>
<th>RDA</th>
<th>OFSP</th>
<th>GT1</th>
<th>GT2</th>
<th>GT3</th>
<th>GT4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>0-0.5</td>
<td>650a</td>
<td>59.9</td>
<td>59.5</td>
<td>59.4</td>
<td>58.9</td>
<td>58.3</td>
</tr>
<tr>
<td></td>
<td>0.5-1</td>
<td>850a</td>
<td>45.8</td>
<td>45.5</td>
<td>45.4</td>
<td>45.1</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td>1-3</td>
<td>1300a</td>
<td>29.9</td>
<td>29.8</td>
<td>29.7</td>
<td>29.5</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>4-6</td>
<td>1800a</td>
<td>21.6</td>
<td>21.5</td>
<td>21.4</td>
<td>21.3</td>
<td>21.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein (g/day)</th>
<th>Age group (years)</th>
<th>RDA</th>
<th>OFSP</th>
<th>GT1</th>
<th>GT2</th>
<th>GT3</th>
<th>GT4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-0.5</td>
<td>13a</td>
<td>31.5</td>
<td>93.1</td>
<td>106.9</td>
<td>130.8</td>
<td>153.1</td>
</tr>
<tr>
<td></td>
<td>0.5-1</td>
<td>14a</td>
<td>29.3</td>
<td>86.4</td>
<td>99.3</td>
<td>121.4</td>
<td>142.1</td>
</tr>
<tr>
<td></td>
<td>1-3</td>
<td>16a</td>
<td>25.6</td>
<td>75.6</td>
<td>86.9</td>
<td>106.3</td>
<td>124.4</td>
</tr>
<tr>
<td></td>
<td>4-6</td>
<td>24a</td>
<td>17.1</td>
<td>50.4</td>
<td>57.9</td>
<td>70.8</td>
<td>82.9</td>
</tr>
</tbody>
</table>

Samples GT1, GT2, GT3 and GT4 are orange fleshed sweet potato-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively. *Food and Nutrition Board, (1989), ^Alasfoor, Rajab and Al-Rassasi, (2007).

The high contribution of the OFSP-based composite porridges to RDAs for protein and energy are due to their reported high concentrations in the composite flours (Table 2). In addition, the contributions of protein that are above the RDA, are non-toxic to the body because it was slightly above the protein requirement[37]. However, it is recommended that protein intake should not be...
more than twice the RDA for protein [37]. Reduction in the contribution of energy and protein to the RDA with an increase in age is due to an increase in the body needs during growth. For example, energy is needed for metabolic activities, body maintenance while protein is for growth and development in children. In order to meet the protein and energy RDAs of the older children, intake of more than 100 ml of the OFSP-based composite porridge is recommended.

### 3.4. Contribution (%) of calcium, iron and vitamin A of porridge from OFSP-based composite flours towards the RDA for children aged 6-59 months

Table 5 shows the calcium, iron and vitamin A contribution (%) of porridge from OFSP-based composite flours to the recommended dietary allowances for children aged 6-59 months. Findings show that the porridge from composite flours contributed more than 100% of the required iron. However, the porridge from OFSP flour only contributed 48% of the RDA for iron in children aged 6-59 months. The results further indicate that the mean calcium contributions of composite flours were between 45.9 and 95.7% of the RDA for children aged 6-59 months. Findings further show that the vitamin A contribution was above 100% in OFSP, GT1 and GT2 while those of GT3 and GT4 were below 100%. The high contributions of iron, zinc, calcium and vitamin A were due to high concentrations as indicated in Table 3. Iron and vitamin A are non-toxic in the body [37,44] and therefore their high contribution levels in the OFSP-based composite flour have no health concern. Therefore, adoption of the OFSP-based flours and their proper preparations may greatly contribute to the reduction of mineral and vitamin A deficiencies among children aged 6-59 months.

<table>
<thead>
<tr>
<th>Contribution to RDA</th>
<th>Ca</th>
<th>Fe</th>
<th>Vitamin A</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP flour</td>
<td>6.5</td>
<td>48.0</td>
<td>442</td>
</tr>
<tr>
<td>GT1</td>
<td>45.9</td>
<td>196.0</td>
<td>322</td>
</tr>
<tr>
<td>GT2</td>
<td>56.3</td>
<td>245.0</td>
<td>125</td>
</tr>
<tr>
<td>GT3</td>
<td>72.3</td>
<td>488.0</td>
<td>76</td>
</tr>
<tr>
<td>GT4</td>
<td>95.7</td>
<td>974.0</td>
<td>32</td>
</tr>
<tr>
<td>RDA</td>
<td>700.0</td>
<td>10.0</td>
<td>450 ‡</td>
</tr>
</tbody>
</table>

Samples GT1, GT2, GT3 and GT4 are orange fleshed sweet potato-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively. ‡ µg/100 g, † are in mg/100 g. The recommended levels of the nutrients considered adequate for most healthy children aged 6-59 months [37].

### 3.5. Functional properties of orange fleshed sweet potato-based composite flours

The functional properties determine the application and use of food materials for various food products. The results for the solubility and swelling power of OFSP and OFSP-based composite flours are shown in Table 6. The decrease in solubility of flours was not significant (p=0.423) while swelling power significantly (p=0.048) decreased from 0.9 to 0.5%. The non-significant decrease in solubility of OFSP-based composite flours is attributed to dilution effect of sugars in the flours by addition of skimmed milk and amaranth leaves powder that have lower sugar content than OFSP flour. According to [45], high sugar content favors formation of hydrogen bonds increasing solubility hence low solubility of OFSP-based composite flours due to low sugars. Therefore, the developed composite flours are soluble in water and would be suitable for making porridge. The study findings are in
agreement with those of [46] who reported a solubility of 3.12% in orange flesh sweet potato-sorghum-soy blend at a ratio of 40:40:20.

Table 6. Functional properties of orange fleshed sweet potato-based composite flours on dry weight basis.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Solubility (%)</th>
<th>Swelling power (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP flour</td>
<td>2.9±0.3</td>
<td>0.9±0.2</td>
</tr>
<tr>
<td>GT1</td>
<td>2.7±0.3</td>
<td>0.7±0.1</td>
</tr>
<tr>
<td>GT2</td>
<td>2.3±0.0</td>
<td>0.6±0.1</td>
</tr>
<tr>
<td>GT3</td>
<td>2.1±1.3</td>
<td>0.5±0.0</td>
</tr>
<tr>
<td>GT4</td>
<td>1.5±0.8</td>
<td>0.5±0.1</td>
</tr>
<tr>
<td>p-value</td>
<td>0.423</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Values in the Table are means ± standard deviations of duplicate determinations. Means in the same column with different superscripts are significantly (p<0.05) different. GT1, GT2, GT3 and GT4 are OFSP-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively.

The swelling power indicates the degree of water absorption of the starch granules in the flour [47] during heating. As a result of water absorption and heat, starch granules swell resulting into a viscous paste. There were no significant (p>0.05) differences in the swelling power among the composite flours but significant (p=0.048) difference was observed between composite flours and OFSP flour (control). The increasing levels of amaranth leaves and skimmed milk powders decreased the swelling power of composite flours. This is probably due to reduction in the number of starch granules and lower carbohydrate content as a result of the addition of skimmed milk and amaranth leaf powders. The low swelling power of the composite flours makes them suitable for use in preparation of gruels used as weaning foods as they will result in porridges of low viscosity. Findings from this study are consistent with those of other studies [48] that reported a decrease in swelling power in sweet potato-based composite flour with increasing soybean flour amount added.

3.6. Physical properties of orange fleshed sweet potato-based composite flours

Table 7 presents the physical properties of orange fleshed sweet potato-based composite flours on dry weight basis. Water absorption capacity is the ability of flour to absorb water and swell, for improved consistency in food. It is desirable for food systems to improve yield and consistency and to give body to the food [49]. The water absorption capacity (WAC) of OFSP and OFSP-based composite flours ranged from 62.8 to 58.0%. There was a significant (p<0.05) decrease in WAC between OFSP and OFSP-based composite flours. On the other hand there was no significant (p>0.05) decrease between samples GT2, GT3 and GT4. Orange fleshed sweet potato flour had the highest water absorption capacity, while GT4 had the lowest water absorption capacity. The high WAC recorded for the OFSP flour could be due to its particle size, giving a higher surface area and high capillarity in the flour [50]. The values of the water absorption capacity obtained for the flours correspond with the swelling power and solubility. This implies that the low water absorption capacity of the OFSP-based composite flours obtained in this study will be desirable for making thinner gruel with high caloric density per unit value [47]. [21] reported no significant (p>0.05) decrease in WAC at 20% soy flour substitution in sweetpotato flour but a significant decrease with higher levels of soy flour.
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Table 7. Physical properties of orange fleshed sweet potato-based composite flours on dry weight basis.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Water absorption capacity (%)</th>
<th>Oil absorption capacity (%)</th>
<th>Bulk density (g/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFSP</td>
<td>62.8±0.4</td>
<td>25.4±0.4</td>
<td>0.6±0.1</td>
</tr>
<tr>
<td>GT1</td>
<td>59.1±0.1</td>
<td>60.7±0.3</td>
<td>0.5±0.0</td>
</tr>
<tr>
<td>GT2</td>
<td>58.5±0.5</td>
<td>60.5±0.1</td>
<td>0.6±0.0</td>
</tr>
<tr>
<td>GT3</td>
<td>58.0±0.1</td>
<td>68.1±0.7</td>
<td>0.6±0.1</td>
</tr>
<tr>
<td>GT4</td>
<td>58.0±0.5</td>
<td>73.5±0.7</td>
<td>0.6±0.1</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Values in the Table are means± standard deviations of duplicate determinations. Means in the same column with different superscripts are significantly (p<0.05) different. S GT1, GT2, GT3 and GT4 are OFSP-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively.

The oil absorption capacity (OAC) of OFSP and OFSP-based composite flours significantly (p<0.05) increased from 25.4 to 73.5% (Table 7). Oil absorption is important because oil acts as flavour retainer and increases mouth feel of foods, improves palatability and extends shelf-life especially in bakery or meat products where fat absorptions are desired [51]. The increase in OAC in OFSP-based composite flours is attributed to the high protein content due to addition of skimmed milk and amaranth leaves powders. The high protein content of composite flours enhanced hydrophobicity by exposing more polar amino acids to the fat [52]. This observation is consistent with the reports of [48], who observed an increase in OAC of composite flours prepared by blending sweet potato flour with maize flour, soy bean flour and xanthan gum from 2.03 to 2.2 g/g. The values observed in this study were higher than those of sweet potatoes flour (10-12%) [53]. This is probably due to addition of skimmed milk and amaranth leaves powders that are rich in proteins. The high OAC of the composite flours indicates that the flours could also be used in making bakery products for infants.

The bulk density of the flours ranged from 0.5 to 0.6 g/ml, with GT1 having the lowest. The bulk densities obtained during the period in this study were insignificantly (p>0.05) very low and this indicates that the flours would be of an advantage in preparation of complimentary foods [54]. The study findings are in agreement with those reported by [46] who reported a bulk density of 0.6 g/ml in orange flesh sweet potato, sorghum and soybean blend. Bulk density is a measure of heaviness of a flour sample and this gives an indication that the relative volume of the composite flours in a package will not reduce excessively during storage.

3.7 Sensory acceptability of porridges from OFSP-based composite flours

Table 8 presents results from the mean sensory scores of porridge from OFSP-based composite flours. The degree of liking for the general appearance of porridges from composite flours decreased from 7.4 to 3.7 with increase in the substitution levels of skimmed milk and amaranth leaves powders. Porridge from GT2 had the highest score (7.4) while that from GT4 had the lowest score (3.7). There were no significant (p>0.05) differences in the scores for the appearance of porridge from GT1 and OFSP flours, GT2 and OFSP flour. This could be attributed to the low levels of amaranth leaves powder added. However significant (p<0.05) differences were observed between GT1, GT2, GT3 and GT4 (Table 8). This is attributed to the increased levels of amaranth leaves powder added to the OFSP flour. The scores for the colour of porridges from composite and OFSP flours followed the same trend as that of general appearance. This is probably because colour is one the attributes assessed under appearance.
Table 8. Sensory acceptability of porridges from OFSP-based composite flours.

<table>
<thead>
<tr>
<th>Sample</th>
<th>General appearance</th>
<th>Colour</th>
<th>Aroma</th>
<th>Taste</th>
<th>Thickness</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT1</td>
<td>6.5b±1.6</td>
<td>6.2a±1.9</td>
<td>6.0ab±1.8</td>
<td>5.8b±1.9</td>
<td>6.6ab±1.7</td>
<td>5.6bc±2.3</td>
</tr>
<tr>
<td>GT2</td>
<td>7.4a±1.3</td>
<td>6.8±2.1</td>
<td>6.7a±1.9</td>
<td>6.8a±2.0</td>
<td>6.9±1.9</td>
<td>6.8±1.9</td>
</tr>
<tr>
<td>GT3</td>
<td>4.9c±2.2</td>
<td>4.6b±2.1</td>
<td>5.2b±1.7</td>
<td>5.3b±2.2</td>
<td>6.4b±2.1</td>
<td>5.3bc±2.03</td>
</tr>
<tr>
<td>GT4</td>
<td>3.7d±2.5</td>
<td>3.3c±2.4</td>
<td>3.9±2.1</td>
<td>4.2c±2.2</td>
<td>5.9±1.8</td>
<td>4.6c±2.4</td>
</tr>
<tr>
<td>OFSP flour</td>
<td>7.1ab±1.3</td>
<td>6.8a±1.9</td>
<td>6.0ab±2.1</td>
<td>5.8ab±2.2</td>
<td>6.8ab±2.0</td>
<td>6.2ab±1.5</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.272</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Values in the Table are means±standard deviations of 30 semi and untrained panelists. Means in the same column with different superscripts are significantly (p<0.05) different. Samples 288, 921, 546 and 719 are orange fleshed sweet potato-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively.

The scores for the aroma of porridges from composite flours ranged between 3.9 and 6.7. Porridge from GT2 had the highest score while GT4 had the lowest score. Significant differences in the scores were noted between GT2, GT3 and GT4 then OFSP and GT4. This is attributed to the increase in the levels amaranth leaves powder added. The similar trend was also observed in the scores of taste for the porridges. The scores for thickness of porridges from composite flours ranged from 5.9 to 6.9. There were significant (p<0.05) differences in the scores of thickness for porridges from GT2 and GT4. The overall acceptability expresses how the consumer or the panelist generally accepts the product. It was observed that porridge from GT2 was most accepted (6.8) while that from GT4 was least accepted (4.6). The high score for the overall acceptability of porridge from GT2 could be due to the familiarity of taste, aroma and colour. Findings from this study were in agreement with those who reported by other researchers [46] whereby overall acceptability scores of 5.72 to 6.96 in porridges from orange flesh sweet potato, sorghum and soybean blend were recorded.

3.8. Pasting properties of the OFSP-based composite flours

Figure 1 shows the pasting properties OFSP-based composite flours. The results indicate that OFSP flour recorded the highest peak (1046.5 cP) and final (191.5 cP) viscosities. The peak and final viscosities of the composite flours decreased with increasing levels of substitution of skimmed milk and amaranth leaves powders. The decrease in peak viscosity was from 464.0 to 180.0 cP while that of final viscosity was from 122.5 to 116.5 Cp. The decrease in peak and final viscosities of composite flours compared to OFSP flour is attributed to the high fibre contents of the composites due to addition of amaranth leaves powders. Fiber competes with starch for the limited amount of water available in food system [55] thus reducing the viscosity. Final viscosity is the change in viscosity after holding cooked starch at 50°C and it indicates the ability of starch to form a viscous paste or gel after cooking and cooling [45,56,57]. The results in Figure 1 indicate that composite flours had lower final and peak viscosities than OFSP flour. This is nutritionally beneficial in infant formulas [58], since a less viscous porridge is a better weaning food for children.
392 Figure 1: Rapid Visco-Analyzer pasting curves for OFSP and OFSP-based composite flours. Samples A, B, C and D are orange fleshed sweet potato-based composite flours with skimmed milk powder at substitution levels 20, 25, 30 and 35% respectively while amaranth leaves powders were 2, 2.5, 5 and 10% respectively.

The setback or viscosity of cooked paste is the viscosity after cooling the paste to 50°C. The extent of increase in viscosity on cooling to 50°C reflects the retrogradation tendency [59], a phenomenon that causes the paste to become firmer and increasingly resistant to enzyme attack [60]. It thus has an effect on digestibility. Higher setback values are synonymous to reduced paste digestibility [61], while lower setback during cooling of the paste indicates lower tendency for retrogradation and subsequently higher digestibility [62]. The low setback values for the OFSP-based composite flours indicate that their pastes would have higher stability against retrogradation [63] than OFSP flour. The lower set back viscosities also imply that the porridge when consumed by children will be easy to digest.

The pasting temperature of OFSP-based composite flours increased from 79.9 to 77.9°C while the pasting time ranged between 3.7 and 3.8 minutes with increase in substitution levels of skimmed milk and amaranth leaf powders. The pasting temperatures were significantly (p < 0.05) higher than that of OFSP flour (74.3°C). The pasting temperature provides an indication of minimum temperature required for cooking the flours [64]. The high pasting temperature of OFSP-based composite flours implies that more energy will be required for cooking porridge from OFSP-based composite flours than for flour from OFSP.

4. Conclusion

Incorporation of skimmed milk and amaranth leaf powders resulted in nutrient enhanced orange fleshed-based composite flours with improved functional properties. Scaling up production of OFSP-based composite flours has potential to contribute to the reduction of malnutrition among children aged 6-59 months in developing countries.

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Conflicts of Interest: The authors declare no conflict of interest.

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