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Orange-fleshed sweet potato based complementary food provides sufficient vitamin A for infants aged 6-12 months

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Vitamin A deficiency is a major public health problem in developing countries, specifically Ghana. The high beta-carotene content of orange-fleshed sweetpotato (OFSP) may help alleviate vitamin A deficiency because beta-carotene is converted to vitamin A when consumed. It is hypothesized that complementary food formulated with OFSP, rice, soybean and cowpea or peanut would contain >50% of the estimated average requirement (EAR) of vitamin A for infants 6 to 12 months of age. Three different blend formulations (OFSP Rice-1, OFSP Rice-2 and OFSP Rice-3) were prepared. OFSP Rice-1 was prepared with 50% rice, 30% OFSP and 20% soybeans flours as control; OFSP Rice-2 was prepared with 45% rice, 30% OFSP, 20% cowpea flours and 5% vegetable oil; and OFSP Rice-3 was prepared with 55% rice, 20% OFSP, 20% soybeans flours and 5% peanuts. Each formulation was evaluated for its nutritional quality, sensory characteristics and pasting properties using standard AOAC methods, a 9-point hedonic scale, and Brabender viscoamylograph, respectively. All three formulations met >50% EAR for energy (386.2 to 391.8 kcal/100 g), protein (10.4 to 16.9 g/100 g), carbohydrates (68.4 to 72.2 g/100 g), iron (3.6 to 7.6 mg/100 g) and beta-carotene (2112 to 7879 µg/100 g). OFSP-Rice2 had a significantly higher concentration of beta-carotene (7879.20 µg/100 g). OFSP-Rice3 had the highest acceptability score of 8.0, highest peak viscosity (41.5 BU), highest viscosity after holding (37.0 BU), and the highest final viscosity (53.5 BU). Rice with 20 or 30% OFSP may provide >50% EAR of vitamin A for infants 6 to 12 months of age. This may provide an acceptable vitamin A rich food that could help alleviate vitamin A deficiency in Ghana.

Key words: Complementary food, orange-fleshed sweetpotato (OFSP), vitamin A, broken rice.

INTRODUCTION

Vitamin A deficiency is a major public health concern in developing countries. It is associated with night blindness, xeropthalmia, skin and hair diseases, growth retardation and impaired immune system (Dada et al., 2002;

McCaffery et al., 2003). In Africa, 32% of children under the age of five are estimated to be vitamin A deficient, with a 1.5% prevalence of xerophthalmia within the same age group (UN SCN, 2004). In Ghana, vitamin A is of particular concern, since the prevalence of vitamin A deficiency is 72% (GHS, 2005; GDHS, 2008; WHO, 2002). A diverse diet including foods such as fruits, leafy green vegetables, and animal products can provide sufficient vitamin A. Additionally, foods rich in beta-carotene such as orange-fleshed sweetpotato (OFSP) provide sufficient dietary vitamin A (Low et al., 2008). However, infant diets in low income countries consist largely of starchy staples such as maize, millet and sorghum and lack the vitamins and minerals needed for good health and development (WHO/UNICEF, 2012). A lack of vitamin A during these critical growth periods contribute to growth-stunting during the first 2 years of life, with potential adverse consequences for child development and later adult health, highlighting the need to provide infants with food adequate in vitamin A to prevent the risks associated with vitamin A deficiency. The present study was designed to investigate the use of orange-fleshed sweetpotato, rice and other locally available ingredients as potential complementary food to help combat vitamin A deficiency among children 6 to 12 months of age.

Several funded programs have been initiated by both local researchers and international organisations to help solve this problem of micronutrient deficiency. Programs such as promotion of complementary foods with cereal-legume mix (Annan et al., 1995; Amagloh et al., 2011), provision of high oral doses of vitamin A (Bruno et al., 2001), micronutrient fortification of cereal flours (WFP Report, 2012), use of sprinkle powder (Zlotkin et al., 2001), and lipid-based supplementation (Adu-Afarwuah et al., 2008; Adu-Afarwuah et al., 2010) have all been employed to address this problem. Although, these interventions have been effective, they are limited in reach and often expensive, especially for rural areas where majority of the poor live. Therefore, it is important for all stakeholders to consider new approaches that may involve locally available raw materials.

One such approach is the use of the biofortified root crop, orange-fleshed sweetpotatoes (OFSP) as a way of enhancing the nutritive value of infant foods. Earlier work conducted among children in Peru found OFSP to be a good ingredient for complementary food (Espinola et al., 1998). Others have also found improvement in vitamin A status after children were fed diets containing OFSP (Jaarsveld et al., 2005; Amagloh et al., 2012). Again, work by Bonsi et al. (2014) found a high acceptability of OFSP blends with roasted maize meal. However, the use of rice, especially broken rice fractions and OFSP as a complementary food has not been explored in Ghana. In Ghana, like many African countries, the use of rudimentary tools and practices affect the quality of the milled rice. The resultant product usually contains unhusked grains, bran and husk fractions, making it less attractive and less competitive on the market, however high in micronutrients (Appiah et al., 2011). Using broken rice fractions together with OFSP as a composite blend in complementary food may provide an alternative use for rice cultivated in Ghana and improve the beta-carotene content of infant food, thus improving vitamin A status of infants. It is hypothesized that complementary food formulated with OFSP, rice and soybean, cowpea or peanut would contain >50% of the estimated average requirement (EAR) of vitamin A for infants 6 to 12 months of age

The aim of this study was therefore to produce three different blend formulations from OFSP flour, broken rice flour, soybean, peanut and/or cowpea and evaluate their nutritional quality, sensory characteristics and pasting properties.

MATERIALS AND METHODS

Orange-fleshed sweetpotatoes (OFSP) tubers and broken rice fractions (*Oryza sativa*) were the major ingredients for all the formulations. OFSP were obtained from Tuskegee University, Tuskegee, Alabama, while the broken rice fraction was obtained from rice milling center in Afefe in the Volta Region of Ghana. Other ingredients used for the blend formulations such as soybeans (*Glycine max*), peanuts (*Arachishypogaea*), cowpea (*Vignaunguiculata*) and vegetable oil were purchased from a local market in Accra, Ghana.

Samples preparation

The OFSP was peeled, washed and sliced to about 2 mm using an electric slicer. OFSP slices were blanched in water at 90°C for 5 min, and cooled immediately in cold water. The blanched OFSP was dried in an oven at 50°C for 16 h. Milling was done using the pin mill followed by the hammer mill into fine flour.

Low grade broken rice fractions was cleaned and sorted to remove chaff and immature grains before milling. The rice was milled into fine flour using a hammer mill. The procedure for aflatoxin elimination in peanut (CRSP, IUFoST, 2012) was followed to sort out the immature, shriveled, discolored and damaged kernels from the clean kernels. This involved heat blanching of the groundnuts in a preheated oven at 140°C for 15 min. The peanuts were allowed to cool and thereafter, the reddish seed coats manually removed. The peanuts were then roasted in an oven at 140°C for 30 min with intermittent turning every 10 min. For blends that contained peanut, a proportion of the roasted peanut that would give a 5% of peanut in the final blend was mixed with specific weight of the broken rice fraction before milling. This was done in order to obtain a uniform mixture.

Full-fat soy flour and cowpea flour were obtained following a method from Plahar et al. (1997). Cleaned soybeans or cowpea were soaked in water for one hour and blanched for 20 min in hot water. The hot water was drained from the soybean with a sieve and immediately refreshed with cold water to avoid over blanching. The blanched soybean was allowed to cool, spread thinly on a stainless steel tray and dried in an oven at 60°C for 8 h. The disc attrition mill (Hunt No. 2A Premier Mill, Hunt & Co., UK) was used to dehull the dried soybeans. The soybean was then winnowed and milled in the hammer mill to obtain fine flour.

Cowpea was dehulled manually by hand after blanching in hot

Table 1. Formulations and product characteristics of OFSP-rice blends.

Blend formulations	Product characteristics and limiting sensory attribute
OFSP Rice-1	Yellowish-orange flour which when reconstituted and cooked becomes creamy yellowish porridge.
OFSP Rice-2	Yellowish-brown flour which when reconstituted and cooked becomes deep yellowish porridge. Beany flavor
OFSP Rice-3	Light-yellowish orange flour which when reconstituted becomes a creamy yellowish porridge.

OFSP Rice-1: rice flour 50%: OFSP 30%: soybean 20%; OFSP Rice-2: rice flour 45%: OFSP 30%: cowpea 20%: Oil 5%; OFSP rice-3: rice flour 55%: OFSP 20%: soybean 20%: peanut 5%.

water for 20 min and dried in an oven at 60°C for 8 h. Dehulled cowpea was milled using a hammer mill to obtain fine flour. The three weaning blends were prepared with appropriate portions of the various flours weighed separated and mixed thoroughly using a manual mixer (WFP, 2012).

Blend formulation

Based on work done by Annan et al. (1995), the blends (Table 1) were formulated with ingredients that will provide vitamin A, and also meet at least 50% of the estimated dietary allowance (EAR) of vital nutrients. Again, work done by Bonsi et al. (2014), found an acceptability of 20 to 30% of OFSP in maize meal. Based on this, 20 and 30% OFSP was chosen for this work. Three different blend formulations were prepared from orange-fleshed sweetpotatoes flour, broken rice fraction flour and soybean flour with or without peanut and OFSP, broken rice and dehulled cowpea. Flour from broken rice fractions was the main energy source. This was combined with OFSP flour and soybeans, a source of protein and fat. In other formulations, dehulled cowpea was used as the protein source. In order to meet the Codex Alimentarius Commission (CAC) criteria for fat content of complementary foods, oil was added to the formulation containing cowpea during manual mixing of the flours in that formulation. Peanut was also added to increase the fat content, and to improve aroma. In formulations containing peanut, the peanut was mixed with the broken rice before milling.

Proximate composition

Nutritional analysis to determine proximate composition (energy, carbohydrates, protein, fat, ash) and mineral/vitamin composition (iron, vitamin A, calcium and phosphorus) were done using standard procedures (AOAC, 2000). Carbohydrates were calculated by difference. Energy values were determined using Atwater factors 3.47, 8.37 and 4.00 for protein, fat and carbohydrates, respectively (Eyeson and Ankrah, 1975).

Carotenoid analysis

Carotenoid analysis was carried out using the method of Rodriguez-Amaya and Kimura (2004). This involved extraction with cold acetone using a mortar and pestle, partitioned to petroleum ether and taking the absorbance at 450 nm.

Calculation

$$\text{Total carotenoid content (µg/100 g)} = \frac{A \times \text{Vol. (mL)} \times 104 \times 100}{A1\% \ 1 \ cm \times \text{Sample wt (g)}}$$

Total carotenoid content (µg/100)/6 = µg RE/100 g

Where: A= absorbance, Vol. = 50 ml A1%1cm = Absorbance co-efficient of β-carotene in PE (2592).

Pasting properties

Pasting characteristics of the various formulations were determined with a Brabender Viscoamylograph (Model VA-VE, Brabender Instruments, South Hackensack, NJ) equipped with a 700 cm-g sensitivity cartridge. A 10% slurry (db) of each flour was prepared with distilled water and the slurry heated uniformly (1.5°C per min) from 25 to 95°C, held to cool at the same rate to 50°C (Shuey et al., 1982). The resulting amylograms from triplicate determinations gave the pasting temperatures, peak viscosities, viscosity at 95°C, paste stability, ease of cooking and set back viscosities. Ease of cooking was calculated as the difference between time to reach gelatinization temperature and time to obtain maximum viscosity during heating (Adeyemi et al., 1987).

Consumer acceptability studies

To determine acceptability of porridge prepared from the various formulated OFSP-Rice meal, 60 care-givers, with children between 6 and 12 months were recruited from child-care/weighing centers in the La Nkwantanan-Madina District of Accra, Ghana. A total of 5 weighing centers were visited. Mothers who consented to be part of the study were recruited. Mothers were made to rank their acceptability of the various porridges based on colour, appearance, taste, aroma, mouth feel, consistency and overall acceptability on a 9-point hedonic scale, with 1 representing "dislike extremely" and 9 representing "like extremely" (Larmond, 1977). Permission was sought from the Administrative Director of the University Hospital. Mothers were also made to sign a consent form before the study was carried out.

Data analysis

Data was analyzed using statistical package for social sciences (SPSS) version (17.1.01). Significantly different means were separated using Fishers least significant difference (LSD), assuming a level of significance at p<0.05.

RESULTS

Product characteristics and blend formulations

The different blend formulations and product

Table 2. Mean sensory scores for OFSP rice-blends from consumer acceptability test**.

Sensory characteristics	OFSP Rice-1	OFSP Rice- 2	OFSP Rice-3
Appearance	6.82 ± 1.99^a	7.05 ± 1.85^a	7.07 ± 1.52^a
Colour	6.63 ± 1.71^a	6.49 ± 1.86^a	6.70 ± 1.64^a
Aroma	6.37 ± 1.81^a	6.28 ± 1.79^a	6.67 ± 1.79^a
Taste	7.07 ± 1.62^a	6.68 ± 1.97^a	7.16 ± 1.56^a
After taste	6.84 ± 1.78^{ab}	6.46 ± 1.94^a	7.32 ± 1.38^b
Consistency	7.56 ± 1.44^a	7.19 ± 1.82^a	7.40 ± 1.49^a
Mouth feel	6.84 ± 1.77^a	6.96 ± 1.91^a	7.39 ± 1.44^a
Acceptability	7.80 ± 1.37^a	7.36 ± 1.9^a	8.00 ± 0.96^b

Means within a row not followed by the same superscript letter(s) are significantly different ($p<0.05$). **Interpretation of scores: 1=dislike extremely; 2= dislike very much; 3=dislike moderately; 4=dislike slightly, 5= neither like nor dislike; 6=like slightly; 7= like moderately; 8= like very much; 9=like extremely. OFSP Rice-1: Rice flour 50%: OFSP 30%: Soybean 20%; OFSP Rice-2: Rice flour 45%: OFSP 30%: Cowpea 20%: Oil 5%; OFSP Rice-3: Rice flour 55%: OFSP 20%: Soybean 20%: Peanut 5%

characteristics of the three blends, as perceived by selected expert panel, are shown in Table 1. The product colour ranged from light-yellow to yellowish-brown flour and when reconstituted, resulted in a creamy yellowish to deep yellowish porridge.

Acceptability studies

Table 2 gives the results of consumer acceptability studies for porridge prepared from the three formulated OFSP-Rice blends. After-taste was the only sensory characteristics that showed significant differences between the three blends. OFSP Rice-3 had a significantly higher score for aftertaste than OFSP Rice-2 but not significantly different from OFSP Rice-1.
Appearance, colour, aroma, taste, consistency and mouth feel did not show significant differences between the three products. OFSP-Rice 3 showed a significantly higher acceptability than the other two formulations: OFSP Rice-1 and OFSP-Rice 2. The mean scores of sensory attributes of all three products ranged from "like slightly" to "like very much". Out of the 60 caregivers who were interviewed, 43.3% preferred OFSP Rice-3, 38.3% preferred OFSP Rice-1, while 18.3% preferred OFSP Rice-2. OFSP Rice-3 was the most preferred blend

Nutrient composition of OFSP-rice blends

The proximate composition, beta-carotene levels, vitamin C and mineral content of the OFSP rice blends are shown in Table 3. OFSP Rice-1 (control) had a significantly higher content of protein, ash, vitamin C and iron. OFSP Rice-2 was significantly high in energy, carbohydrates, beta-carotene and zinc. OFSP Rice-3 was significantly high in fat and moisture content, which

may be due to addition of peanut. As the quantity of rice increased and OFSP decreased (OFSP Rice-3), the beta-carotene content decreased significantly, as compared to the control (OFSP Rice-1). OFSP Rice-2 had a relatively higher beta-carotene content. This could be due to addition of oil which may be fortified with vitamin A (Gain, 2007). Addition of soybean (OFSP Rice-1 and OFSP Rice-3) resulted in a blend with relatively higher protein content than cowpea (OFSP Rice-2). This is because the protein content of soybeans is higher than that of cowpea. A combination of peanut and soybeans as a source of fat gave a significantly higher fat content than when oil or soybean alone was used as the source of fat. The energy, carbohydrates, protein, iron and beta-carotene contents of all 3 blends met more than 50% of EAR for infant. Fat, vitamin C, calcium and zinc contents were slightly lower than the recommendations set by CAC.

In all three OFSP-Rice formulations, ash levels fell within the recommended range of <3%. However, the ash content in OFSP-Rice 2 was significantly lower ($p<0.05$) than the other two formulations. This could be due to the soybean and peanut content of the OFSP-Rice-1 and OFSP-Rice 3, respectively which increased the ash content.

Pasting properties

The pasting properties of OFSP rice samples are presented in Table 4. Differences were observed, among the blended formulae in their behavior during heating and cooling. Among the three formulations, OFSP Rice-3 had the highest peak viscosity, highest viscosity after holding, and final viscosity, while OFSP Rice-1 exhibited much lower values of peak viscosity, pasting temperature and final viscosity.

Table 3. Proximate composition, mineral, vitamin and carotene content of OFSP- rice blends.

Nutrient composition	OFSP Rice-1	OFSP Rice-2	OFSP Rice-3	EAR[1] (7 to 12 month)
Energy (kcal/100 g)	386.24±0.78[a]	391.78±1.43[b]	390.41±0.21[b]	400kcal
Carbohydrate (g/100 g)	66.85±0.28[a]	72.19±0.15[b]	66.42±0.78[a]	95g/d
Fat (g/100 g)	5.69±0.49[a]	6.82±0.25[b]	7.05±0.01[b]	30g/d
Protein (g/100 g)	16.90±0.19[a]	10.42±0.49[b]	15.32±0.10[c]	9.6g
Ash (g/100 g)	2.44±0.06[a]	1.88±0.28[b]	2.20±0.21[c]	<3%[2]
Moisture (g/100 g)	8.13±0.02[a]	8.70±0.08[b]	9.02±0.09[c]	<5%[2]
β-carotene (µg/100 g)	2649.60[a]	7879.20[b]	2112.50[c]	-
RE (µg/100 g)	441.60[a]	1313.20[b]	352.10[c]	400µg/d
Vitamin C (mg/100 g)	3.36±0.63[a]	2.13±0.15	1.91±0.16[b]	25mg/d
Iron (mg/100 g)	7.57±0.16[a]	7.49±0.56[a]	3.67±0.22[b]	11.6mg/d
Zinc (mg/100 g)	0.51±0.00[a]	1.49±0.21[b]	1.34±0.25[b]	6.9mg/d
Calcium (mg/100 g)	33.03±4.68[a]	28.22±2.36[a]	24.85±2.37[a]	417mg/d

Values are means of triplicate determination ± standard deviation. Means within a row not followed by the same superscript letter(s) are significantly different ($p<0.05$). [1]Estimated Average Requirement.[2]Recommended ranges of nutrients not EAR (Codex, 2010). OFSP Rice-1: Rice flour 50%: OFSP 30%: Soybean 20%; OFSP Rice-2: Rice flour 45%: OFSP 30%: Cowpea 20%: Oil 5%; OFSP Rice-3: Rice flour 55%: OFSP 20%: Soybean 20%: Peanut 5%

Table 4. Pasting properties of OFSP-rice blends.

Parameter	OFSP Rice-1	OFSP Rice-2	OFSP Rice-3
Pasting Temp (°C)	79.6±4.5[a]	75.5±1.0[a]	82.6±0.2[a]
Pasting time (min)	20.2±3.1 [a]	17.5±0.7[a]	22.3±0.1[a]
Peak viscosity(BU)	18.0±2.8[a]	19.5±2.1[a]	41.5±0.7[b]
V Hold at 90°C (BU)	17.5±3.5[a]	19.0±2.8[a]	37.0±0.0[b]
Final viscosity(BU)	30.0±3.1[a]	30.5±4.9[a]	53.5±3.6[b]
Break down(BU)	0.5±0.70[a]	0.5±0.7[a]	3.5±0.7[b]
Set back(BU)	27.0±3.6[b]	25.0±2.1[b]	20.5±2.3[a]

Means bearing different superscripts along a row are significantly different ($p\leqslant0.05$). OFSP Rice-1: Rice flour 50%: OFSP 30%: Soybean 20%; OFSP Rice-2: Rice flour 45%: OFSP 30%: Cowpea 20%: Oil 5%; OFSP Rice-3: Rice flour 55%: OFSP 20%: Soybean 20%: Peanut 5%

DISCUSSION

The focus of this study was to explore the use of broken rice fraction and orange-flesh sweetpotato as potential food ingredients that can add value to complementary foods. The fat content of peanut and/or vegetable oil aid in the absorption of the vitamin A and improved aroma, while soybean and/or cowpea serves as protein source for the formulated complementary food.

Nutrient content of food that meet at least 50% of the recommended daily intake are said to be adequate in that nutrient (Codex, 2010). The energy, carbohydrates, protein and vitamin A contents of all the three formulated blends were very high and met the recommended amount set for infant foods. Rice was the main source of carbohydrates in this formulation. The carbohydrate content of OFSP Rice-2 was significantly different from the control (OFSP Rice-1) but there was no significant difference when compared with OFSP Rice-3. Even

though, the rice content of the control was 5% less, there were some contributions of carbohydrate from the OFSP, thus making the total carbohydrate content in the control vs. OFSP Rice-3 about 80:75% which may account for the insignificant difference. Protein is important, especially during the weaning period to prevent protein-energy malnutrition, which is usually observed among children in developing countries (Achidi et al., 2016). Protein source came from either soybean or peanut or cowpea. As compared with the control (OFSP Rice-1), when soybean was replaced with cowpea (OFSP Rice-2), there was a significant decrease in protein; however, this was more than the EAR set for proteins. Similar observations were made when the same quantity of soybeans was added. The observation in this study implies that the developed blend products with addition of rice and soybean or cowpea may be a good source of protein for complementary foods (Welch et al., 2000; Broughton et al., 2003; Amjad et al., 2006), and would

Table 5. Nutrient composition of broken rice and soybean.

Nutrient composition	Low grade broken rice fraction	Soybean
Energy (Kcal/100 g)	354.5	447.5
Carbohydrate (g/100 g)	76.94	36.79
Fat(g/100 g)	0.70	18.10
Protein (g/100 g)	10.12	34.37
Ash (g/100 g)	0.84	5.14
Moisture (g/100 g)	11.20	5.60
Vitamin C (mg/100 g)	0.60	1.40
Iron (mg/kg)	20.25	6.50
Zinc (mg/kg)	13.62	49.70
Calcium (mg/100 g)	20.00	339.30
Phosphorus (mg/100 g)	161.60	218.40

supply the needed protein-energy requirements to meet infants' growth demands.

Guidelines set by Codex Alimentarius Commission (CAC) seek to ensure that complementary foods contain adequate amounts of vitamin A andiron. There was a significant improvement in both vitamin A levels and iron levels in all three formulations. As the quantity of rice increases with a decrease in OFSP (OFSP Rice-3), the beta-carotene content decreased significantly, as compared to control (OFSP Rice-1). However, with the same quantity of OFSP and a decreased portion of rice (OFSP Rice-2), there was a significantly higher beta-carotene content. This result was not expected since the same quantity of OFSP was in each formulation. However, the observed difference in OFSP Rice-2 could be due to addition of vegetable oil which may be fortified with vitamin A. Fortification of vegetable oil with vitamin A is a recommended practice in Ghana to help combat vitamin A deficiency (Gain, 2007). The beta-carotene content in all the three formulations were high enough to meet recommendations set by CAC. This indicates that substituting rice with either 20 or 30% of OFSP will significantly improve the beta-carotene content which will subsequently improve vitamin A status. These results are similar to results obtained by Bonsi et al. (2014). It also supports observations by Tchum (2009) who showed that bio-fortification of complementary foods such as maize meal and millet flour with local sources of pro-vitamin A carotenoids can enhance vitamin A status.

Iron content of OFSP Rice-3 was relatively lower as compared to the control. There was no significant difference between iron content of OFSP Rice-2 when compared with control. Iron is a very important nutrient which improves the cognitive function of children (Lozoff et al., 1998; Beard et al., 2003). Complementary foods must contain the right amount of iron for infants 6 to 12 month of age because the iron content in breast milk may no longer be sufficient to meet infant demands during this period (Dupont, 2003). In this study, iron content of all

three formulations met more than 50% of the EAR. This may have come from contributions from soybeans, cowpea and the broken rice fractions. Soybeans and cowpea may also contribute good amounts of iron (Broughton et al., 2003; White and Broadley, 2005). Broken rice fractions may have contributed to the high iron content of these products since it has lot of bran which is rich in iron as shown in Table 5. Despite this, high phytate levels in rice, soybean and cowpea may inhibit its bioavailability (Welch et al., 2000; Hurrel, 2004). Vitamin C is known to enhance absorption of non-heme iron from cereals (Hallberg, 1989). In this study, the vitamin C content of all the three products was very low. As such, enrichment of the blends is recommended with sources of vitamin C to enhance the absorption of iron in these formulations. Some local vitamin C sources that can be explored are oranges, mangoes and pineapples.

Apart from vitamin C, fat and zinc contents, were lower than recommendations set by CAC. As compared to the control (OFSP Rice-1), addition of oil improved the fat content significantly but not in amounts that met 50% of the EAR. It is however important to add oil to weaning formulations when cowpea is used as protein source because cowpea has insignificant amount of fat (Nagai et al., 2009). This study recommends addition of vegetable oil above 5% in order to meet guidelines set by CAC as well as the EAR for infants 6 to 12 months of age. When peanut was used as source of fat, there was significant improvement in fat content when compared with control. Even though the fat content in peanut formulation (OFSP Rice-3) was slightly higher when compared with oil as a source of fat (OFSP Rice-1), there was no significant difference between the two. The significant increase in fat content observed for OFSP Rice-3 as compared to control was as a result of adding both soybeans and peanut. Addition of peanuts and soybean may be a better source of fat than soybean or vegetable oil alone as the main fat contributor.

Zinc content was low in all three formulations. However,

zinc content of OFSP Rice-2 and OFSP Rice-3 were significantly higher when compared with control (OFSP-Rice 1). None of the formulations met 50% EAR for zinc. Zinc is an important nutrient which helps with growth, development and cognitive function of children (Salgueiro et al., 2001). Zinc deficiency is of particular concern because it can lead to long-term deficits in growth, immune function, cognitive and motor development, behavior, and academic performance (Black, 1998; Brown, 2009; WHO, 2013). As such, complementary food should include the right amount of zinc to help with child growth and development. Some important sources of zinc that can be explored to improve complementary foods includes mushrooms, nuts and seed and dark chocolate.

Despite the low nutrient content of OFSP Rice-3, it recorded the highest acceptability score of 8.0 indicating "like very much". Even though there was no limiting sensory attributes for both OFSP Rice-3 and control (OFSP Rice-1), addition of groundnut significantly improved the acceptability of the formulations (OFSP Rice-3) when compared with the control. The formulations with cowpea and oil (OFSP Rice -2) gave the least acceptability mean of 7.4. Even though this mean score indicates "like moderately", the significant effect for OFSP Rice-2 was on the aroma and aftertaste. Again, aftertaste and acceptability were the only sensory attributes that showed significant differences between the three products. This low acceptability of OFSP Rice-2 could be due to the beany flavor and taste of the cowpea which panelists thought as unpleasant. Even though all three formulated products had a high acceptability scores, the most preferred formulation based on most sensory attributes was OFSP Rice-3.

Colour and appearance are important sensory attributes which affect the perception of other attributes, such as aroma, taste and flavor (Hutching, 1999). Colour, aroma and taste can therefore affect the way children perceive food. Parents often determine sensory attributes on behalf of their children, and may know whether food will be liked or disliked by their child. The orange colour of the OFSP gave the porridge a nice and pleasant colour which ranged from creamy yellowish to deep yellowish porridge.

Differences were observed, among the blended formulae in their behaviour during heating and cooling. Among the three formulations, OFSP Rice-3 had the highest peak viscosity, highest viscosity after holding, and final viscosity while the control (OFSP Rice- 1) exhibited much lower values of peak viscosity, pasting temperature and final viscosity. This might be due to higher value of rice in the formulation and higher rate of absorption and swelling of starch granules. The results suggest that the samples will behave differently during cooking and processing. Additionally, differences in the protein composition of the peanut and cowpea as well as the soybean in these formulations could account for the pasting behaviours (Batey and Curtin, 2000; Morris et al.,

1997). The prepared formulae largely displayed rather low peak viscosities, in the range of 18.0 to 41.5 BU. Having a low viscosity value, these composite flours could be incorporated into certain food products in higher concentrations without becoming too viscous (Cornell, 2004). The low viscosity of these blend flours is also beneficial for infant nutrition since they cannot tolerate solid diet due to their digestive system and eating skills that are not yet fully developed (Walker et al., 1999; Muyonga et al., 2001). The lower breakdown of these composite flours might produce a less cohesive paste which would be beneficial during food processing (Moorthy, 2004).

Conclusions

This study has demonstrated that broken rice fraction can be used with orange flesh sweetpotato to provide a nutritionally adequate and culturally acceptable complementary food for Ghanaian children 6 to 12 months of age with >50% of EAR for vitamin A. The addition of OFSP makes it a useful ingredient that can help improve vitamin A content of complementary foods. The use of broken rice fractions, which otherwise would be used as animal feed or left as waste, may be a cheaper alternative in infant feeding. Women in rice-growing communities must be encouraged to use broken rice fractions with OFSP as a composite blend in complementary food. This may provide an alternative use for the rice cultivated in Ghana as well as boost the socio-economic status of farmers and individual entrepreneurs, especially women in the local rice value chain.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adu-Afarwuah S, Lartey A, Brown KH, Zlotkin S, Briend A, Dewey K (2008). Home fortification of complementary foods with micronutrient supplements is well accepted and has positive effects on infant iron status in Ghana. American J. Clin. Nutr. 87:929-938.

Adu-Afarwuah S, Lartey A, Zeilani M, Dewey KG (2010). Acceptability of lipid-based nutrient supplements (LNS) by Ghanaian infants and pregnant or lactating women. Maternal Child Nutr. 86:1-13.

Achidi UA ,Bernard T, Noel T, Hilaire MW, Marcel NM, Lucy TE , Fossi T (2016). Quality Evaluation of Nine Instant Weaning Foods Formulated from Cereal, Legume, Tuber, Vegetable and Crayfish Intl. J. Food Sci. Nutr. Eng. 6(2):21-31.

Amagloh FK, Weber JL, Brough L, Hardacre A, Mutukumira AN, Coad J (2011). Complementary food blends and malnutrition among infants in Ghana: A review and a proposed solution. Sci. Res. Essays 7(9):972-988.

Amagloh FK, Hardacre A, Mutukumira AN, Weber JL, Brough L, Coad J (2012). Sweet potato-based complementary food for infants in low-income countries. Food Nutr. Bull. 33(1):3-10.

AmjadIqbal, Iqtidar K, NediaAteeq, Muhammed SK (2006). Nutritional quality of important food legumes. Food Chem.97(2):331-335.

Annan NT, Plahar WA (1995). Development and quality evaluation of a soyfortified Ghanaian weaning food. Food Nutr. Bull. 16(3):263-269.

AOAC (2000). Official Methods of Analysis. Association of Official AnalyticalChemists, Washington, DC.

Appiah F, Guisse R, Dartey PKA (2011). Postharvest losses of rice from harvesting to milling in Ghana. J. Stored Products Postharvest Res. 2(4): 64-71.

Batey IL, Curtin BM. (2000). The effects on the pasting viscosity of starch and flour of different operating conditions for the Rapid Visco Analyzer. Cereal Chem. 77:754-760.

Beard JL, Connor JR. (2003). Iron status and neural functioning. Annu Rev Nutr., 23:41-58.

Black MM (1998). Zinc deficiency and child development. Am. J. Clin. Nutr. 68(2 Suppl):464S-469S.

Bonsi EA, Plahar WA, Zabawa R (2014). Nutritional Enhancement of Ghanaian Weaning Foods Using the Orange Flesh Sweetpotato (*Ipomeabatatas*). AJFAND, 14:5.

Brown KH. (2009). Preventive zinc supplementation among infants, preschoolers, and older prepubertal children. Food Nutr. Bull. 30(Suppl 1):S12-36

Bruno de B, José M, Goodman T (2001). Vitamin A supplementation and the control of vitamin A deficiency: Conclusions. The United Nations University. Food Nutr. Bull. 22:3.

Broughton WJ, Hernández G, Blair MW, Beebe S, Gepts PL, Vanderleyden J (2003). Beans (*Phaseolus* spp.)-model food legumes. Plant Soil 252:55-12.

Codex, JOINT FAO/WHO (2010). Food Standards Programme Codex Committee On Nutrition And Foods For Special Dietary Uses Thirty second Session Santiago, Chile 1 – 5 November 2010, "Proposed Draft Revision of the Guidelines on Formulated Supplementary Foods for Older Infants and Young Children," (CAC/GL 08-1991) at Step 4.

Dada VK (2002). Xeropthalmia: A National Health Problem. J. Ind. Med. Assoc15:179-18022.

Dupont C. (2003). Protein requirements during the first year of life. Am J Clin. Nutr. 77(suppl):1544S-1549S.

Espinola N, Creed-Kanashiro H, Ugaz ME, van Hal M, Scott G (1998). Development of a sweet potato-based instant weaning food for poorly nourished children six months to three years old. CIP Program Report. International Potato Center: Lima, Peru, pp. 295-302.

Gain (2007). Faire Tached'Huile Cooking Oil Fortification in West Africa. Business Innovation to Combat Malnutrition Case Study Series http://siteresources.worldbank.org/CGCSRLP/Resources/1Fairetache dhuilecase.pdf

GDHS (Ghana Demographic Health Survey) (2008). ICF Macro. Calverton, Maryland, USA 2008. Ghana Health Service. (2005). ICF Macro. ICF, Macro.

Hallberg L, Brune M, Rossander L (1989). Iron absorption in man: ascorbic acid and dose-dependent inhibition by phytate. Am. J. Clin. Nutr. 49, 140-144.

Hurrel R.F(2004). Phytic acid degradation as a means of improving iron absorption. International Journal absorption. Inter. J. Res.74: 445-452

Hutchings JB Food Color and Appearance, Aspen Publishers, Gaithersburg, Md. 1999.

Low Jan W, Jaarsveld van P. (2008). The Potential of Golden Bread Buns Biofortified with Beta-carotene-Rich Sweet potato to Add Value to Rural Diets and Increase Profits of Rural Bakers in Central Mozambique. Food Nutr. Bull. 29(2):98-107.

Lozoff B, Klein NK, Nelson EC, McClish DK, Manuel M, Chacon ME (1998). Behavior of infants with iron-deficiency anemia. Child Dev. 69:24-36.

McCaffery PJ, Adams I, Maden M, Rosa ME (2003). Too much of a good thing: Retinoic acids as an endogenous regulator of renal differentiation and exogenous teratogen. Euro. J. Neurosci. 18:457-472.

Moorthy SN (2004). Tropical sources of starches. In: A.C. Elliason (Ed.), Starch in Food England. Wood head Publishing Limited pp. 321-359.

Nagai T, Staatz JM, Bernsten RH, Sakyi-Dawson EO, Annor GA.(2009) Locally Processed Roasted-Maize-based Weaning Foods Fortified With Legumes: Factors Affecting Their Availability And Competitiveness In Accra, Ghana. AJFAND, 9(9):1927-1944.

Plahar WA, Nti CA, Annan NT. (1997). Effect of soy-fortification method on the fermentation characteristics and nutritional quality of fermented maize meal. Plant Foods for Human Nutr. 51:365-380.

Rodriguez-Amaya DB, Kimura M (2004). Harvest Plus Handbook for Carotenoid Analysis. Harvest Plus technical Monogragh Series 2. Washington DC and Cali. International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture, pp. 35-36.

Tchum SK, Newton S, Tanumihardjo SA, Fareed KNA, Tetteh A, Owusu-Agyei S. (2009). Evaluation of A Green Leafy Vegetable Intervention In Ghanaian Postpartum Mothers. Afr. J. Food Agric. Nutr. Dev. 9(6):1294-1308.

USAID Peanut Collaborative Research support Program (CRSP) and IUFoST (2012). Processing for Aflatoxin Elimination in Peanut Products (Reduction below Regulation Thresholds). Training Workshop Manual. CSIR-Food Research Institute.

UN SCN United Nations Standing Committee on Nutrition. (2004). Fifth Report on the World Nutrition Situation. Geneva: United Nations Standing Committee on Nutrition.

Welch RM, House WA, Beebe S, Cheng Z (2000). Genetic selection for enhanced bioavailable levels of iron in bean (*Phaseolus vulgaris* L.) seeds. J. Agric. Food Chem.48:3576-3580.

WFP (2012). Tackling Malnutrition in Northern Ghana, Scale up-3 of Community-based Milling and Fortification Training in Northern Ghana.

White PJ, Broadley MR. (2005). Biofortifying crops with essential mineral elements. Trends in Plant Science 10:586-593.

WHO (2013). Zinc supplementation and growth in children Biological, behavioural and contextual rationale http://www.who.int/elena/bbc/zinc_stunting/en/

Zlotkin SH, Arthur P, Antwi KY, Yeung G. (2001). Treatment of anemia with microencapsulated ferrous fumarate plus ascorbic acid supplied as 'Sprinkles' to complementary (weaning) foods. Am. J. Clin. Nutr. 74:791-795.