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Formulation and characterization of sweetpotato-based complementary food

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Abstract: A sweetpotato-based complementary food was developed in order to promote the utilization of orange-fleshed sweetpotato (OFSP) towards reduction of vitamin A deficiency in Ghana. Four blends of complementary flours made up of OFSP, millet and soybean were formulated based on the composition of the individual flours. These formulations were done to meet the nutrient requirement of babies (6 months to 3 years) in accordance with CAC requirements. Drum drying was used to process the flour blends into instant complementary foods. The most preferred formulation (50% OFSP, 15% millet and 35% soybean flours) determined through sensory evaluation was assessed for some nutrients and microbial safety. It had significantly ($p < 0.05$) higher protein (16.96%) and β-carotene (0.53 mg/100g) content than the control complementary foods. Ash and fat were comparable to that of a commercial complementary food. In addition, it had a significantly higher iron and potassium content compared with weanimix and a commercial complementary food (CCF). Yeast and mould was <3 $\log_{10}$ cfu/g, Total Plate Count, <5 $\log_{10}$ cfu/g, while *Escherichia coli* and *Staphylococcus aureus* were not present. This indicates the product is safe for consumption. This complementary food will support efforts to reduce vitamin A deficiency in Ghana while promoting OFSP for food and nutrient security.

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PUBLIC INTEREST STATEMENT

The orange-fleshed sweetpotato (OFSP) has high levels of beta-carotene, which is a precursor of vitamin A. Due to issues with vitamin A deficiency in Sub-Saharan Africa, it has been the focus of many scientists, as a dietary approach to help eradicate vitamin A deficiency. Therefore, adoption of the OFSP-based complementary food developed will help diversify the uses of sweetpotato and will provide an alternate healthy and nutritious food for most infants. Food industries will also have a new recipe for a complementary food, making use of dietary sources of nutrients often demanded by the current consumer. Due to the relatively high vitamin A content, it will also help with efforts to reduce vitamin A deficiency in Sub-Saharan Africa. The diversification and utilization of OFSP will help efforts to achieve food and nutrient security in Sub-Saharan Africa.

Subjects: Food Analysis; Food Microbiology; Product Development

Keywords: orange-fleshed sweetpotato; vitamin A deficiency; food and nutrient security; drum drying; microbiology

1. Introduction

Complementary foods are foods and liquids other than breast milk or infant formulas required during the second part of the first year of life for both nutritional and developmental reasons and also to enable transition from milk feeding to family foods (Koletzko et al., 2008). After 6 months of age, breast milk is not enough to meet the macro- and micronutrient requirements of infants (Ijarotimi & Keshinro, 2013; Koletzko et al., 2008). Infants also develop the ability to chew; hence, begin showing interest for foods other than milk, therefore, there is the need to introduce healthy complementary foods. According to the Codex Alimentarius Commission, CAC (2008), complementary foods should be of appropriate nutritional quality and energy to complement the nutrients obtained from breast milk for infants and family foods for younger children.

A number of complementary foods have been developed. In Africa, especially in Ghana, most of these complementary foods are cereal-based (Amagloh et al., 2012a). They are mostly formulated with maize as the major ingredient and complemented with soybean, cowpea and/or groundnut. The legumes are added to improve upon the fat and protein content of the food. However, over the years the problem with malnutrition, especially micronutrient deficiencies of vitamin A, iodine and iron, have led to the supplementation of complementary foods (Bhandari et al., 2001; Lutter et al., 2008; Nestel et al., 2003). Vitamin A and iron deficiency are amongst the world's most prevalent nutritional problems (Amagloh et al., 2012a; Lutter et al., 2008).

Sweetpotato as a complementary food has been identified as a viable product both for supplementing the nutritional needs of babies in developing countries while enhancing the utilization of the crop. A number of studies by Ijarotimi and Ashipa (2006), Sanoussi et al. (2013) and Haque, Hosain, Khatun, Alam, and Gani (2013) have, thus, been conducted in this wise.

Some varieties have high amount of β-carotene which is a precursor of vitamin A (Burri, Chang, & Neidlinger, 2011; Picha & Padda, 2009); hence, could help reduce vitamin A deficiency amongst children. Notwithstanding the high energy content of sweetpotato and other micronutrients such as vitamin A, C, potassium, iron and zinc, it is low in protein and fat contents; hence, the need to complement it with legumes and/or cereals when being used in complementary foods.

Sweetpotato in Ghana is being promoted but there are limited diversified products from the crop, which will encourage its consumption. It is characterized by high moisture content; hence, high perishability. The roots unlike other staples in Ghana are sweet, and this has been a challenge in its acceptance especially when processed into already existing food forms. There is, therefore, the need to diversify OFSP into forms that are acceptable especially for children due to the high β-carotene (a provitamin A) content of the roots. This is because vitamin A deficiency is a public health problem in Ghana with prevalence around 35.6% (Egbi, 2012).

The major drawback in the research works on sweetpotato-based complementary foods including those by Ijarotimi and Ashipa (2006), Sanoussi et al. (2013) and Haque et al. (2013) was the viscous nature of the resultant complementary foods. Amagloh et al. (2013) employed three processing methods (extrusion, roller drying and oven toasting) to resolve this drawback. These processes also improved the nutrient composition of the complementary foods. However, to further improve the nutrient composition of the sweetpotato-based complementary food and to enhance the suitability of sweetpotato in the baby food industry, studies into the use of the OFSP, which has higher β-carotene compared with the cream flesh used, is needed. Moreover, soybean, which is the protein and fat source for the complementary food has been reported to lack methionine and cysteine (Edema, Sanni, & Sanni, 2005). These amino acids are abundant in cereals such as millet or maize. Therefore, a blend of cereals and legumes in the formulation of a complementary food, which was lacking in the study by Amagloh et al. (2013), will improve on its protein quality.

Therefore, the objective of this study is to formulate a sweetpotato-based complementary food from an OFSP (*Bohye*), millet and soybean. The characteristics of the complementary food formulated including acceptability, nutrient and microbial levels are also studied.

2. Materials and methods

2.1. Source of raw materials

The *Bohye* variety of sweetpotato was obtained from the farms of the Crops Research Institute (CSIR-CRI), Fumesua. The pearl millet and soybean were obtained from the open market in Accra.

2.2. Preparation of flour from the sweetpotato, millet and soyabean

Sweetpotatoes weighing 78.25 kg were sorted, peeled, chipped and dried in a hot air oven at 60°C for 12 h. Weight of chipped sweetpotatoes before drying was noted to be 49 kg. The dried sweetpotato chips were then milled in a hammer mill into flour. Millet weighing 27 kg was sorted, sieved, washed and dried at 60°C for 2 h and then milled into flour using the hammer mill. Soybean weighing 24 kg was also sorted and roasted for 15 min. It was then dehulled and milled into flour. All the flours were packed into high density polyethylene bags and stored in a cool dry room ready for formulation and analysis.

2.3. Proximate and mineral analysis of samples

Proximate composition of flour samples and product formulated were determined using AOAC (1990) methods. Minerals in the samples were determined using AOAC (2005) methods with slight modifications. Into a digestion tube 1 g of the sample was weighed, 15 ml of concentrated Nitric acid (HNO_3) added to each sample and digested for 30 min at 150°C in a digester in a fume chamber. The sample was digested until the solution was pale yellow, and allowed to cool. Ten mililetres of concentrated perchloric acid (70% $HClO_4$) was added and the digestion continued at 200°C until the solution was colourless. After complete digestion, the solution was cooled slightly and 80 mL of distilled water added. The mixture was boiled for about 10 min and filtered through Whatman No. 42 filter paper into 250 mL volumetric flask. The solution was then made to the mark with distilled water.

2.4. Determination of Ca, Mg, K, Zn and Fe

The concentrations of Ca, Mg, K, Zn and Fe were determined using Atomic Absorption Spectrometer (Spectra AA220FS Model). The mineral contents in the samples were then calculated and results expressed in mg/100g.

2.5. Formulation of complementary food

Based on the macronutrients of the individual flours with reference to the levels of macronutrients required of complementary foods as developed by CAC (2011), material balance was used to estimate the minimum amount of each portion of flour to meet the standard (Figure 1). A range for the various proportions was, therefore, developed and mixture design (from the Statgraphics Centurion software) was used to formulate the complementary food blend. The formulation is as shown in Table 1.

2.6. Processing of the complementary food blends

The flour blends produced from the formulations were drum dried. To 2.5 kg of flour blend, 2.37 L of water was added; therefore, 95% of water per weight of flour blend was added to each of the samples and kneaded into dough. The dough was then introduced onto the drums. The pressure of steam used was 2.5 bar and temperature, 126.9ºC while revolution of drums was at 0.1911 rev/min. Thin dry films were produced from the drum drying and these were then milled into flour and packaged for further analysis.

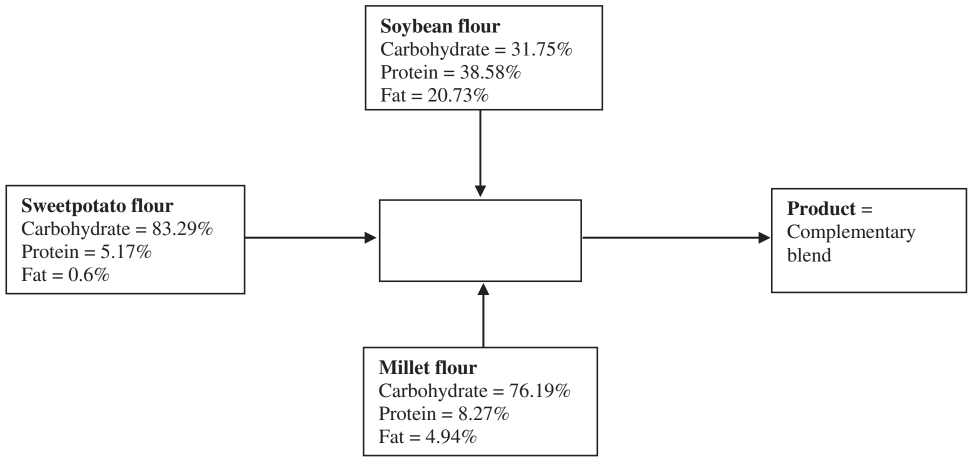


Figure 1. Design of material balance used for flour amounts for the blend.

Table 1. Formulation for the complementary food blend

Runs	Flour compositions (%)			Other ingredients (% of total flour composition)		
	Sweetpotato flour	Millet flour	Soybean flour	Sugar	Salt	Powdered milk
1	60	10	30	5	0.5	5
2	60	15	25	5	0.5	5
3	50	15	35	5	0.5	5
4	55	10	35	5	0.5	5

Formulations obtained from the statgraphics centurion from the range determined through material balance reference to the CODEX, 2011 requirement for complementary foods

2.7. Sensory evaluation

2.7.1. Preparation of samples and sensory evaluation

2.7.1.1. Weaning mix (control sample). A well-known maize-based complementary food (weanimix) was used as the control sample in this study and as such included in the sensory evaluation. Into a cooking utensil on fire was added 500 mL of water. Hundred grammes of weanimix flour was mixed with 250 mL of water to form slurry. The slurry was then poured into the boiling water which already had 0.5 g of salt. The resulting slurry was then stirred using a wooden ladle consistently until a paste was formed. The food was cooked for 15 min and after, 20 g of sugar was added.

2.7.1.2. Sweetpotato-based complementary food preparation and sensory evaluation. Five hundred millilitres of water at 85ºC was added to 100 g of the processed sweetpotato-based complementary food flour and stirred with a wooden ladle consistently until a paste was formed. These food samples were served in disposable cups in a random order for panellists to assess. The sensory evaluation was carried out in a sensory lab (a closed room) in the Department of Food Science and Technology, KNUST. The sensory lab had adequate lighting from daylight or the sunlight and panellists were seated in individual booths. The evaluation was carried out for 3 days between 10:00 am and 3:00 pm. Fifty untrained panellists (38 breastfeeding mothers and 12 non-breastfeeding mothers who have fed babies before) were asked to assess the coded complementary food samples in terms of colour, thickness, consistency, sweetness, aftertaste and overall acceptability using a 5-point hedonic scale (1-dislike very much and 5-like very much). Water was provided for panellists to rinse their mouth in-between tasting of the complementary foods.

2.8. β-carotene determination of complementary foods and orange-fleshed sweetpotato flour

The β-carotene content of the most preferred complementary food, control samples (a well-known commercial complementary food and Weanimix) and the OFSP flour was determined using the method described by Imungi and Wabule (1990). A Shimadzu HPLC equipment was used and it was made up of an LG6 pump, a UV-Visible detector, a CR6 recorder, ODS-RESERVED PHASE column and a Ryhodyne 1725 injector. Mobile phase was made up of acetonitrile 70%, 20% dichloromethane and 10% methanol. The flow rate was also 1 mL/min and wavelength 450 nm.

2.9. Microbial determination of complementary foods

2.9.1. Staphylococcus aureus enumeration

Sixty grammes of Baird Parker Agar was suspended in 1 L of distilled water. The solution was heated with frequent agitation and boiled for 1 min to completely dissolve the medium. It was then autoclaved at 121ºC for 15 min. After cooling, 50 mL of Egg Yolk Tellurite supplement (#7983) was added and mixed thoroughly before dispensing. One gramme of sample was dissolved in 10 mL of peptone water and serial dilutions made into test tubes. After which 1 mL of sample was transferred into each of the plates containing Baird Parker Agar. The distribution of sample of the surface of the agar was done using a bent glass rod. The inoculum was then allowed to absorb to the surface of the media and then plates inverted. They were incubated at 37ºC for 48 h. Colonies were then counted on a colony counter after incubation (Vanderzant & Splittstoesser, 1992).

2.9.2. Enumeration of coliforms (Escherichia coli)

To prepare the medium, 37 g of Rapid' *Escherichia coli* 2 Agar was dissolved in 1 L of distilled water. It was then mixed until a homogenous mixture was obtained. It was then heated gently while agitating frequently and then boiled until powder was completely dissolved. It was then autoclaved at 121ºC for 15 min. One gramme of sample was weighed into 10 mL Butterfield's Phosphate Buffer diluents. It was homogenized in a blender at high speed to dissolve sample. Serial dilutions were made. After, 1 mL of the sample solutions was pipette into a sterile Petri dish and 15 mL melted medium rapidly poured into it. Petri dish was swirled to mix the contents and then left to solidify. Petri dishes were then inverted and incubated at 44ºC for 24 h for enumeration of *E. coli*. The colonies formed after incubation was counted using a colony counter (Lauer, Martinez, & Patel, 2007).

2.9.3. Enumeration of yeast and mould

Yeast and mould was enumerated using a conventional method. Twenty-five grammes of sample was dissolved in 225 mL of sterile distilled water. A serial dilution of this solution was then prepared by pipetting 1 mL of solution in 9 mL of distilled water in a test tube. One mililetre of each dilution prepared was transferred into their corresponding sterilized Petri dishes. The potato dextrose agar was melted in a water bath and 15 mL poured into the Petri dishes. It was swirled to disperse medium and sample solution evenly. It was then allowed to solidify and then incubated at 28 ºC for 72 h. The colonies formed were then counted using a colony counter (Luna-Guzman & Barrett, 2000).

2.9.4. Enumeration of total plate count

Total Plate Count (TPC) was enumerated using the conventional method. One gramme of sample was dissolved in 10 mL of distilled water. A serial dilution of the solution was prepared by pipetting 1 mL of solution in 9 mL of distilled water in a test tube. One mililetre of each dilution prepared was transferred into their corresponding sterilized Petri dishes. Plate Count Agar was melted in a water bath and 15 mL poured into the Petri dishes. It was swirled to disperse medium and sample solution evenly. It was then allowed to solidify and then incubated at 37ºC for 24 h. Colonies formed were then counted using a colony counter (Luna-Guzman & Barrett, 2000).

2.10. Statistical analysis
All data collected were in triplicate, with the exception of the sensory evaluation. Data was expressed as mean and standard deviation and one-way analysis of variance and Tukey's HSD test was used to ascertain any statistical differences at 95% confidence interval. Pearson's correlation was also used to establish any relationships between the sensory attributes.

3. Results and discussion

3.1. Flour yields of sweetpotato, millet and soybean
Weight of sweetpotato, millet and soybean after drying and milling were 12.5 kg, 25 kg and 20 kg, respectively. Millet had the highest yield of 92.6% followed by soybean (83.3%) and sweetpotato (16%) (Figure 2). Sweetpotato had the least yield due to the large amount of water, typical of most roots and tubers (Ogunlakin, Oke, Babarinde, & Olatunbosun, 2012). Fresh sweetpotato could have a moisture content of about 80% (Kamal, Islam, & Aziz, 2013). Cereals and legumes on the other hand are usually dried before storage and sale; therefore, there was not much water to lose before milling.

Soybean had a lesser yield compared to millet due to the dehulling process. Dehulling of soybean is necessary in the development of an infant food because the seed coat has a lot of antinutrients such as trypsin inhibitors, tannins, phytates and more.

3.2. Proximate composition of the flours produced
Moisture content was highest in millet flour compared to the other two flours. This may have been due to the source of materials and different processing method. Soybean, being a legume and a good source of protein and fat, had the highest contents of protein and fat. It also contained the highest amount of ash; making it a relatively higher source of minerals. Sweetpotato had the least fat content (0.6%) (Figure 3). Sweetpotato and millet flours were very high in carbohydrate content.

The variety of sweetpotato used in this study, *Bohye*, had higher protein content (5.17%) than that reported by Dansby and Bovell-Benjamin (2003); they reported a protein content of 1% for another orange-fleshed variety. Protein content of sweetpotato could also be as high as 9.21 to 9.80% depending on the variety (Kamal et al., 2013).

Carbohydrate content of sweetpotato reported by Dansby and Bovell-Benjamin (2003) was, however, higher (90.6%) than that reported in this study (83.29%). Similar to this study, Kamal et al. (2013) reported approximately 80% of carbohydrate content in their sweetpotato flour. The difference may be due to the variety and mode of cultivation (Gichuhi, Kpomblekou-A, & Bovell-Benjamin, 2014). The sweetpotato flour reported by Dansby and Bovell-Benjamin (2003) was hydroponic sweetpotato flour but the exact variety was not specified. Again the protein, fat and

Figure 2. Yield of flours processed from sweetpotato, millet and soybean.

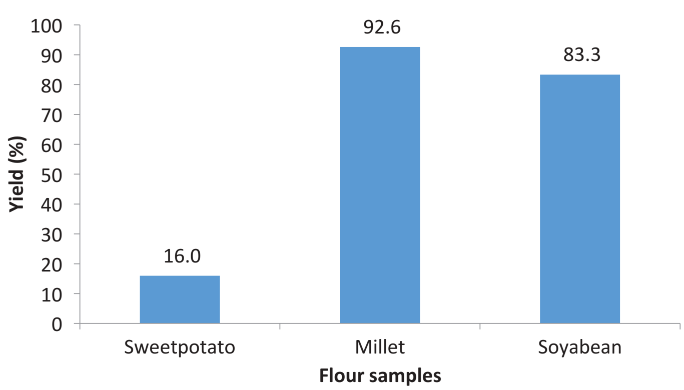
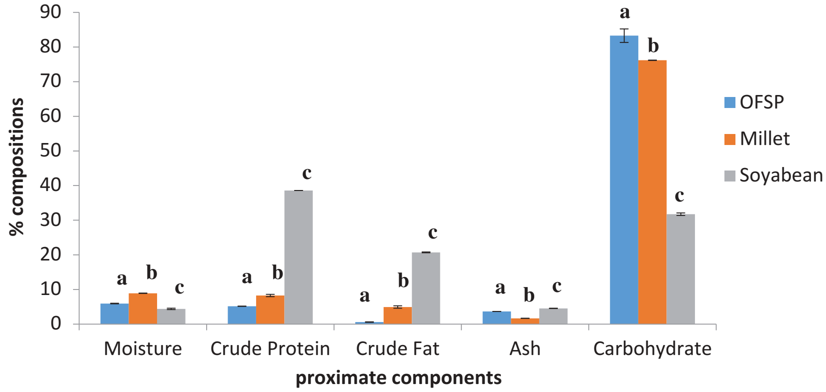


Figure 3. Proximate composition of sweetpotato, millet and soybean flours.

OFSP—Orange-fleshed sweetpotato flour. Error bars represent standard deviation of three determinations
Bars with different superscript are significantly different at 95% confidence level



ash content of the OFSP were higher than reported by Jangchud, Phimolsiripol, and Haruthaithanasan (2003) who also used an orange-fleshed variety. The difference in these components could be due to difference in climate and soil conditions under which the roots were cultivated (Gichuhi et al., 2014). Being a high energy food due to the high starch content, sweetpotato flour, complemented with soybean will help make up for its low protein and fat content, in order to help make the complementary food whole in terms of nutrients.

3.3. Panellists' preference of the products developed

The preference of the drum dried complementary food formulated, with reference to all parameters given, was between "neither like nor dislike (3)" and "Like moderately (4)" on the 5-point hedonic scale. Preference for colour of samples was highest in weanimix (the maize-based complementary food) and formulation 4, followed by formulation 3 (Table 2). The first two formulations, formulation 1 and 2, were relatively the least preferred (Table 2). The thickness and consistency of the OFSP-based complementary foods were more preferred compared to weanimix (Table 2).

The OFSP-based complementary food was smoother with suitable thickness for babies compared with weanimix according to panellists. Bonazzi and Dumoulin (2011) have reported that the drum drying process is suitable for the development of complementary foods and baby cereals. Also, according to Mustafa, Alsaed, and Al-Domi (2014) the drum dryer could also be used to develop food products of good sensorial attributes.

The preference for sweetness of the product was highest in formulation 4, weanimix and formulation 3. These were followed by formulation 2, while formulation 1 was the least preferred. A bitter aftertaste was observed by panellists in formulation 1 which may have affected its score for the sweetness. This is confirmed by a positive strong correlation observed between sweetness and aftertaste ($r = 0.795$, $p < 0.01$); which implies that even if the sweetness was high enough for the product to be preferred more, the bitter aftertaste becomes stronger and leads to the low rating of the product. The bitterness could have resulted from the heat application to the dough (mixture of flour ingredients for the complementary food and water) and/or interaction between the various flours and ingredients during processing. Also, a bitter compound identified in sweetpotato known as ipomeamarone, which may be induced by dry heat application (Uritani et al., 1980) could have been a factor. This compound may have been more distinct in formulations with relatively high sweetpotato content and may have resulted in the relatively least preference for formulations 1 and 2.

In terms of overall acceptability, formulation 3 was the most preferred followed by formulation 4, weanimix and then formulations 1 and 2. The significant factors influencing the overall acceptability was observed to be sweetness and consistency, from the regression analysis conducted

Table 2. Preference of OFSP-based complementary food compared with weanimix

Complementary food formulation	Colour	Thickness	Consistency	Sweetness	Aftertaste	Overall acceptability
1 (60:10:30)	3.30 (0.33)	4.40 (0.20)	4.15 (0.18)	2.60 (0.27)	2.50 (0.32)	2.85 (0.30)
2 (60:15:25)	3.30 (0.26)	3.90 (0.32)	3.85 (0.26)	3.15 (0.25)	2.95 (0.23)	2.70 (0.29)
3 (50:15:35)	4.05 (0.23)	3.40 (0.28)	4.15 (0.25)	3.30 (0.27)	3.30 (0.32)	3.30 (0.28)
4 (55:10:35)	4.00 (0.22)	3.15 (0.25)	3.35 (0.26)	3.25 (0.30)	3.25 (0.20)	3.10 (0.32)
Weanimix (control)	3.70 (0.25)	2.75 (0.27)	3.20 (0.32)	4.25 (0.27)	4.40 (0.23)	4.00 (0.32)

-Sample ratios are represented as (Orange-fleshed sweetpotato:millet:soybean)

-Scale: 1-dislike very much, 2-dislike moderately, 3-neither like nor dislike, 4-like moderately and 5-like very much

Table 3. Regression analysis of sensory attributes with overall acceptability as dependent variable

Factors affecting overall acceptability	Level of significance
Aftertaste	.078
Sweetness	.000
Consistency	.020
Thickness	.354
Colour	.365

Factors affect overall acceptability if "level of significance" is less than 0.05

(Table 3). Sweetness was also found to be a determining factor in the overall acceptability of baked sweetpotato (Chin-Feng et al., 2014).

3.4. Nutrient composition of complementary foods

3.4.1. Proximate and β-carotene composition of complementary foods

The most preferred formulation compared with the control samples (weanimix and the commercial complementary food) had significantly higher amounts of ash, fibre and protein contents. No significant differences were observed between the ash content of the most preferred formulation and the commercial complementary food (Table 4).

The presence of ash is an indication of minerals present in the sample (Owiredu, Laryea, & Barimah, 2013). The ash is relatively higher than what was reported by Bonsi, Plahar, and Zabawa (2014) (1.39–1.98%) and Haque et al. (2013) (1.90–2.14%) in their OFSP complementary foods. However, Adenuga (2010) and Amagloh et al. (2012b) had relatively higher ash content, 2.80–11.25%, in their sweetpotato-based complementary foods developed. FAO (1990) and FAO/WHO/UNICEF (1972) reported that the ash content of a complementary food should be less than 5%. The most preferred sample, therefore, meets this standard.

The fat content of the most preferred sample was significantly higher (6.02%) than the commercial complementary food (3.93%) but lower than weanimix (10.46%) (Table 4). A significant

Table 4. Nutrient composition of complementary foods

Proximate components	Complementary foods			
	3 (50:15:35)	Weanimix	CCF	Sweetpotato flour
Moisture (%)	6.47 ± 0.12^{a}	3.80 ± 0.40^{b}	1.37 ± 0.25^{c}	-
Ash (%)	2.71 ± 0.03^{a}	1.99 ± 0.12^{b}	2.82 ± 0.05^{a}	-
Fat (%)	6.20 ± 0.44^{a}	10.46 ± 2.15^{b}	3.93 ± 0.07^{a}	-
Fibre (%)	1.70 ± 0.07^{a}	1.65 ± 0.19^{a}	1.20 ± 0.08^{b}	-
Protein (%)	16.96 ± 0.60^{a}	15.56 ± 0.24^{b}	14.78 ± 0.20^{b}	-
Carbohydrate (%)	65.95 ± 0.87^{a}	66.55 ± 2.54^{a}	75.91 ± 0.35^{b}	-
β-carotene (mg/100g)	0.53 ± 0.02^{a}	0.15 ± 0.01^{b}	0.33 ± 0.02^{c}	1.11 ± 0.09

-Values are averages of triplicate determinations
-Data is represented as mean ± standard deviation
-CCF—Commercial Complementary Food
-Most preferred sample ratio is represented as (Orange-fleshed sweetpotato:millet:soyabean)
-Values in same row with different superscripts are significantly different at 95% confidence level

difference ($p < 0.05$) was observed between weanimix and the other samples. The higher fat content in weanimix could be attributed to the composition of the product; locally the product is often made with maize, soybean and peanut. Peanut and soybeans contributed to the fat content. The FAO (1990) reports that the fat content of complementary foods should be greater or equal to 12%. CAC/GL 08 (1999) also reports that the fat content should be at least 20%. Although the most preferred product was unable to meet these standards, it was higher than sweetpotato-based complementary food reported by Adenuga (2010) (2.40–2.80%) and Bonsi et al. (2014) (4.30%).

Protein content of the most preferred sample was significantly higher than weanimix and the commercial complementary food (Table 4). It was able to meet the protein standard of FAO (1990) and CAC (2011) standards. Adenuga (2010), however, reported relatively higher protein content (31.50–38.5%). This may have been due to the level of soybean in his formulation of complementary food. According to Arrage, Barbeau, and Johnson (1992) protein quality of food substances are improved upon through the process of drum drying. Although drum drying process reduces some amino acids such as isoleucine and methionine, lysine content is significantly increased. Moreover protein digestibility is improved upon through the process of drum drying (Arrage et al., 1992).

Carbohydrate contributes a lot towards energy in complementary foods. Its content could be high but must be digestible enough for infants and young children to obtain the energy required or needed CAC/GL 08 (1999); CAC (2011). The carbohydrate content obtained (65.95%) compared with the commercial complementary food (75.91%) was significantly ($p < 0.05$) lower but was comparable with that of weanimix (66.55%) (Table 4). Carbohydrate content of the complementary foods were able to meet FAO (1990), CAC/GL 08 (1999) and CAC (2011) standards for carbohydrate. The carbohydrate content was also comparable with what was reported by Bonsi et al. (2014) and Haque et al. (2013) (42.30–54.5%). However, unlike the most preferred complementary food in this study, the complementary foods by Bonsi et al. (2014) and Haque et al. (2013) were not pregelatinized.

The fibre content of the most preferred complementary foods was low (1.70%) and meets the criteria set by CAC/GL 08 (1999) and CAC (2011); which reports that fibre content should be less than 5%. This is because the presence of high quantities of fibre makes the food bulky and induces flatulence CAC/GL 08 (1999); CAC (2011) which is an uncomfortable feeling in infants. Moreover, digestion of high fibre foods is a difficult task for infants, since their digestive system is not well developed at that stage. The fibre content was lower than what was reported by Amagloh et al. (2012b) and Adenuga (2010).

β-carotene is essential for the growth and development of infants and young children. In Sub-Sahara Africa where vitamin A deficiency continues to be a problem, development of a complementary food with high content of β-carotene is essential. Prevalence of vitamin A deficiency has been reported to be around 35.6% in Ghana (Egbi, 2012).

Dietary sources of vitamin A are key to eradicating vitamin A deficiency in Ghana and Africa as a whole (Amagloh et al., 2012a). The β-carotene content of the most preferred sweetpotato-based complementary food was 0.53 mg/100g which was significantly ($p < 0.05$) higher than weanimix (0.15 mg/100g) and the commercial complementary food (0.33 mg/100g). The high β-carotene content of the OFSP flour (1.11 mg/100g) contributed to this significant increase (Table 4).

The β-carotene content obtained was higher than what was reported by Haque et al. (2013) and Bonsi et al. (2014). In both studies, the OFSP was used such that in the studies by Bonsi et al. (2014), the formulation with the highest β-carotene content (0.11 mg/100g) had 50% of OFSP flour. Difference in variety of the OFSP may have resulted in this variation.

According to Koletzko et al. (2008) the recommended daily allowance of vitamin A for infants within the age of 6 months to 3 years is between 350 and 400 μg in a day. Booth et al. (2001) also reported 350 μg (0.35 mg) for infants and 400 μg (0.40 mg) for young children in a day. Using the conversion factor of 12 employed by Jaarsveld et al. (2005) in their study, the vitamin A content in the complementary food developed is 44.17 μg/100g, which is 11–12.6% of the RDA needed by infants and young children.

Being a complementary food, it will contribute to the nutrients obtained by infants and children in other foods they consume. The processing methods used, such as the oven drying of the sweetpotato, drum drying and storage may have affected the β-carotene levels, hence, the low vitamin A content compared to what was reported by Christides, Amagloh, and Coad (2015) in their study of sweetpotato-based complementary food.

3.4.2. Mineral composition of complementary foods

The most preferred sweetpotato-based complementary food had a significantly ($p < 0.05$) higher iron and potassium content. The iron content was 1.95 mg/100 g which was significantly higher than the values obtained for the control samples (commercial complementary food, 1.75 mg/100g and weanimix, 0.69 mg/100g) (Table 5). Given the iron content of the individual flours, the OFSP flour had the highest iron content (2.41 mg/100g). It, therefore, contributed to the relatively high content of iron in the most preferred OFSP complementary food.

Iron deficiency among infants and young children is common; therefore, the need to have enough iron in the diet of infants. It is required for mental and physical well-being of children, and is needed in the synthesis of haemoglobin in the body. The recommended nutrient intake value for iron in infants between ages of 6 months and 3 years is between 1.7 to 11 mg/day (Koletzko et al., 2008). One hundred gramme of the complementary food is, therefore, enough to meet the Recommended Daily Intake (RDI) of infants.

The potassium content was also 56.87 mg/100g, which was significantly ($p < 0.05$) higher than the commercial complementary food and Weanimix (Table 5). This relatively high content of potassium seems to have been contributed more by soybean which had the highest of potassium content compared with sweetpotato flour and millet (Table 5). The range of potassium content recommended in baby formulas for infants is 60–160 mg/100 g (Koletzko et al., 2008). This is slightly higher than the sweetpotato-based complementary food developed. The infant would, therefore, need to acquire the difference from other sources such as breast milk or other foods,

Table 5. Mineral composition of complementary foods

Flour samples	Mineral compositions				
	Ca (mg/100g)	Fe (mg/100g)	Mg (mg/100g	K (mg/100g)	Zn (mg/100g)
CCF	86.87 ± 1.53^d	1.75 ± 0.05^b	233.97 ± 1.20^c	52.08 ± 0.50^a	3.68 ± 0.07^d
Weanimix	1.75 ± 0.73^a	0.69 ± 0.02^a	236.41 ± 2.10^c	48.33 ± 0.08^b	2.18 ± 0.05^c
Soybean	25.07 ± 0.97^c	1.61 ± 0.11^b	380.41 ± 3.30^d	96.11 ± 0.77^c	6.40 ± 0.03^e
OFSP	14.87 ± 0.06^b	2.41 ± 0.02^d	181.39 ± 8.49^b	62.35 ± 0.64^d	2.28 ± 0.04^c
Millet	2.14 ± 0.62^a	0.56 ± 0.02^a	58.30 ± 0.39^a	34.46 ± 0.04^e	1.04 ± 0.04^b
OFSPCF	23.91 ± 0.47^c	1.95 ± 0.06^c	234.81 ± 0.97^c	56.87 ± 1.11^f	0.89 ± 0.04^a
RDI (mg/day)	210–500	1.7–11	30–80	60–160	2–3

-Values are averages of triplicate determinations
-Data is represented as mean ± standard deviation
-OFSP—Orange Fleshed Sweetpotato flour
-RDI—Recommended Daily intake (Koletzko et al., 2008)
-OFSPCF—Orange Fleshed Sweetpotato complementary food 3(50:15:35)
-CCF—Commercial Complementary Food
–Values in same column with different superscripts are significantly different at 95% confidence level

that is, if he/she is able to consume 100 g complementary meal in a day. Besides, the product is a complementary food and is meant to complement breast milk or baby formulas. Potassium is required in the body for regulation of fluid, muscle control and normal functioning of the nerves (Nieman, Butter, & Nieman, 1992).

Magnesium content of most preferred sample was comparable to that of the commercial complementary food and Weanimix. No significant difference ($p > 0.05$) was observed amongst the magnesium content of the most preferred sample, the commercial complementary food and Weanimix (Table 5). Magnesium was highest in soybean flour and may have significantly contributed to the magnesium content of the sweetpotato-based complementary food. Zinc content was, however, observed to be lower than that of the commercial complementary food and Weanimix. A significant difference ($p < 0.05$) was observed amongst these three complementary foods. The zinc content in the sweetpotato-based complementary food was influenced by soybean. Soybean had the highest zinc content of 6.4 mg/100g (Table 5).

Calcium content was highest in the commercial complementary food, 86.87 mg/100g, followed by sweetpotato-based complementary food, 23.91 mg/100g and weanimix, 1.75 mg/100g (Table 5). Most of the commercial complementary foods are fortified, and that could be a reason for the relatively high calcium and zinc contents observed.

Soybean contributed significantly to the calcium content of the complementary food. The milk powder added could have also contributed to it. The RDI of calcium for infants ranges from 210 to 500 mg/day (Koletzko et al., 2008). It can, therefore, be observed that, besides iron content that OFSP flour contributed to, soybean contributed significantly to the mineral composition of the most preferred complementary food. It is, therefore, very important to complement root and tuber or cereal flours with legumes such as soybean to improve upon the mineral content in developing complementary foods.

3.5. Microbial levels of most preferred complementary food

The microbial load or levels in the complementary food was low. The TPC was found to be 2.18 $\log_{10}$ cfu/g (Table 6). This was found to be significantly lower ($p < 0.05$) than the control sample (weanimix) (Table 6). It was also lower than 2.23 to 3.54 $\log_{10}$ cfu/g reported by Sanoussi et al. (2013) in the sweetpotato-based complementary food with a blend of sorghum and soybean. The standard for TPC in complementary foods should be less than 2.70 $\log_{10}$ cfu/g (CAC, 2008).

Yeast and mould count was also low. The most preferred sample had 1.99 $\log_{10}$ cfu/g which was significantly ($p < 0.05$) lower than weanimix (2.03 $\log_{10}$ cfu/g) (Table 6). Again, it was lower than what was reported by Sanoussi et al. (2013) (2.10 to 2.60 $\log_{10}$ cfu/g). The standard for yeast and

Table 6. Microbial levels in complementary food developed

Sample	Complementary foods	
	3 (50:15:35) Log_{10}	Weanimix Log_{10}
Total plate count (cfu/g)	2.18	2.30
Yeast and mould (cfu/g)	1.99	2.03
Coliforms (*E. coli*) (cfu/g)	ND	ND
Staphylococcus aureus (cfu/g)	ND	ND

-Values are averages of triplicate determinations

-Data is represented as mean ± standard deviation

-Most preferred sample ratio is represented as (Orange-fleshed sweetpotato:millet:soyabean)

-ND—Not Detected

-Values in same row with different superscripts are significantly different at 95% confidence level mould in complementary foods has been reported to be less than 2.48 log_{10} cfu/g for ready-to-eat foods made for infants and 3 log_{10} cfu/g for foods that require cooking (CAC, 2008).

E. coli count and that of *Staphylococcus aureus* was not detected. This conformed to what was reported by Sanoussi et al. (2013). However, the standard for *E. coli* in complementary foods should be 0 as reported by CAC (2008). The low microbial count indicates the most preferred sample is safe for consumption. Tang, Feng, and Shen (2003) have reported that the drum drying process can be a clean and hygienic process, if all Good Manufacturing Practices are put in place. Also, if there was any form of contamination during the processing, packaging and storage of the raw materials for the formulation of the complementary foods, the heat being applied by the drum drying could reduce the microbial load.

4. Conclusion

The most preferred formulation for the OFSP sweetpotato complementary food was the blend with 50% OFSP, 15% millet and 35% soybean flours. It had significantly ($p < 0.05$) higher protein (16.96%) and β-carotene (0.53 mg/100g) contents than the control complementary foods. Ash and fat were comparable to that of a commercially available complementary food. In addition, the preferred test product had a significantly higher iron and potassium content compared with the commercial complementary food and weanimix (another commercially available complementary food). The product was safe to consume because it was able to meet the microbial standards set by Codex Alimentarius Commision. OFSP flour could be used to develop a complementary food with improved nutrient properties, when complemented with millet and soybean flours. This when adopted will help with vitamin A deficiency in Ghana and also increase the utilization of OFSP to help achieve food and nutrient security.

It is recommended that the optimization of the drum drying process conditions (moisture content of dough, temperature and time for drum revolution) in the development of the OFSP-based complementary food and the shelf life study of the most preferred OFSP-based complementary food could be studied. Studies on the use of other OFSP varieties and the use of OFSP puree in the development of complementary food through the process of drum drying could also be studied.

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