Original Research Article

NUTRITIONAL QUALITY, FUNCTIONAL PROPERTIES AND SENSORY ACCEPTABILITY OF AN ORANGE- FLESHED SWEET POTATO-BASED COMPLEMENTARY FOOD

ABSTRACT

The study focuses on the development of a complementary food (CF) with the orange-fleshed sweet potato (OFSP) to help address the public health problem of vitamin A deficiency among infants. Experimental research design was used for the study. Fifty six infants aged between 6 and 24 months were purposively sampled, together with their mothers, to evaluate three complementary food (CF) products and a control, code-named GAD, PEA, SAB and KAN respectively. The CF products were formulated from orange fleshed sweet potato, anchovies, onion and tomatoes; and the nutrients and functional properties were determined. A questionnaire and an interview guide were used to collect data to assess the sensory attributes and overall acceptability of the formulated CF products.The results showed that the three complementary foods were nutrient dense, with the moisture content being highest in PEA and lowest in GAD. GAD, PEA and SAB were all high in protein and fibre but low in fat and carbohydrate. KAN (control) was the most acceptable with respect to all the sensory attributes of a complementary food, although its overall acceptability was not significantly different from that of the other three CF products - GAD, PEA and SAB.

Keywords: *Vitamin A; Orange-fleshed sweet potato; Complementary Food; Nutritional Quality*

1. INTRODUCTION

Vitamin A deficiency (VAD) is a public health problem of great concern, especially in low- and middle-income countries. It affects approximately 190 million children under five years of age and leads to many adverse health consequences; including death [1].Vitamin A deficiency affects mainly pre-school-age children, mostly from Africa and South-East Asia. To help avert the effects associated with VAD, numerous strategies have been recommended. These include food fortification, vitamin A capsule supplementation, food diversification and nutrition education.The World Health Organization (WHO) recommends high doses of vitamin A supplementation for infants and children 6–59 months of age [2] to help combat infections, night blindness and other visual impairment conditions. According to Bruin and Kraemer (2013) [3], food–based strategies have been recognized as more workable than other strategies and they are long-term approaches to addressing and controlling VAD disorders. Bruin and Kraemer (2013) [3]further emphasized that showing people how to grow plants rich in vitamin A throughout the year, and how to store and cook them, is the most sustainable long-term approach to combating VAD disorders.

Ghana, like many developing countries, has successfully integrated strategies to deliver vitamin A supplements (VAS) to infants and young children below five years as part of its national health policies, including delivery during routine health visits and immunizations. The latest Ghana Demographic Health Survey (GDHS) findings reveal that among all children aged 6-59 months, only 65 percent received vitamin A supplements in the six months immediately preceding the survey [4].In addition, it has been asserted that efforts to increase access to VAS have had little effect on the prevalence of VAD, perhaps because poor rural families cannot access facilities where VAS are administered [5]. Aside administering VAS, dietary diversification and improvement, which include ensuring regular access to foods that are naturally rich in vitamin A, are also a vital strategy that can be employed to help reduce the prevalence of VAD. There are indications that other dietary interventions could be employed to improve the vitamin A status of children by maximizing the utilization of locally grown food crops in any given setting, which can also augment agricultural productivity and profitability.

With respect to the intake of vitamin A rich food sources, the 2014 GDHS findings report that, among young children aged 6-23 months living with their mother, only 67 percent consumed foods rich in vitamin A on the day or night preceding the survey, suggesting the generally poor dietary intakes of vitamin A rich food sources among children in Ghana [4].

In Ghana, cereals and legumes, such as maize, wheat, millet and rice, being the major staples of several communities, are frequently used for complementary foods for infants and young children [6]. However, these cereal and legume-based complementary foods are usually poor nutritional sources of micronutrients, such as iron, zinc and vitamin A [7]. Again, the alarming issue associated with the frequent consumption of these cereals and legumes is the risk of aflatoxin contamination which affects human health and could dispose many infants and young children to poor growth and development. In addition, the high phytate content of cereals limits the bioavailability of micronutrients, such as iron, calcium, zinc and, in some cases, proteins, which are crucial for the development of infants. Therefore; it is needful to reconsider their usage in developing complementary foods for infants and young children.

It is in this regard that the cultivation of some varieties of the sweet potato which have a high amount of ß-carotene, a precursor of vitamin A, is being promoted in most developing countries. Ample evidence has been obtained regarding the potential impact of the orange-fleshed sweet potato (OFSP) on young children's vitamin A status, and in alleviating vitamin A deficiency [8, 9]. For example, the study by van Jaarsveld et al., (2005) [9] in South Africa revealed that the proportion of children with normal vitamin A status (DR:R < 0.060) in the group who consumed 125 g of boiled and mashed OFSP (1031 retinol activity equivalents/d as beta-carotene), tended to increase from 78% to 87% ($P = 0.096$) but changed insignificantly (from 86% to 82%) in the control group who consumed an equal amount of white-fleshed sweet potato, devoid of beta-carotene for 53 school days ($P = 0.267$). In a similar quasi-experimental intervention study in Mozambique, after controlling for infection/inflammation and other confounders, mean serum retinol increased by 0.100mmol/L (SEM 0.024; P,0.001) in intervention children but didnot increase significantly in control subjects [8].

Low (2013) [10] emphasized that just one small root (100 g) of a medium intensity orange-fleshed sweet potato (OFSP) can meet the daily vitamin A needs of a young child (400 Retinol Activity Equivalents (RAEs). Furthermore, Adenuga, (2010) [11] asserts that owing to the high nutritional value, low price and all- year round availability of roots and tubers, they offer a good alternative to cereal-based complementary foods in reducing the incidence of malnutrition among children.Therefore, because the OFSP is readily available and can be easily accessed by caregivers in Ghana, its potential usage in formulating infant complementary foods (CF) is currently being promoted.

In Ghana, few previous studies have been conducted to investigate the possibility of developing CFs using roots and tubers such as the OFSP [7, 12, 13]. In the study byAmagloh (2012) [13], it was found out that only OFSP-based infant foods contained measurable levels of β-carotene, resulting in significantly higher vitamin A content compared with enriched weanimix (a cereal-based CF) (28.80 vs. 1.20 μg retinol equivalents/100 kcal).Similarly, the study by Bonsi et al (2014) [12] also concluded that the OFSP flour has the potential to be used at a 25% replacement level in a soy-fortified roasted maize meal formulation; and the OFSP is a useful ingredient with the potential to improve the β-carotene or vitamin A content of such a formulation.Bonsi et al's (2014) [12] study sought to evaluate the chemical composition, sensory characteristics and consumer acceptability of four CF formulations developed from the OFSP flour, added to either roasted maize- soy blend or fermented maize-soy blend. The authors further indicated that, to enhance their study,they could have includedweanimix (cereal-legume based CF product) porridge for a comparative evaluation.Bonsi et al (2014) [12]specifically recommended the carrying out of comparative evaluation studies aimed at comparing newly developed OFSP-based infant formulations with other known cereal-legume based CF foods.Amagloh, (2012) [13]also averred that there is a need to conduct more field trials and consumer acceptance studies in Ghana before conclusive recommendations on the use of the OFSP-based infant formulations could be made.

In view of this, the present study focuses on the development of a complementary food from orange fleshed sweet potato. The study assesses the nutritional and functional characteristics as well as consumer acceptability of the OFSP by conducting a sensory analysis of the developed OFSP-based CF products. Specifically, the sensory analysis evaluates the acceptability of the CFs with respect to appearance, taste, texture, aroma and overall acceptability.

2. MATERIALS AND METHODS

2.1 Research Design

The study adopted the experimental research design to determine the influence of varying quantities of the anchovy and OFSP on taste, appearance, aroma and texture of the three CF formulations (GAD, PEA and SAB). The research design had the ability to manipulate precisely the variables in the experimenter's choice of ingredients.

2.2 Population

In this study, the target population was all infants aged between 6 and 24 months who accessed the University of Cape Coast hospital for child-healthcare services, such as growth monitoring and promotion services.

2.3 Study Sample and Sampling Procedures

The researchers adopted the purposive sampling procedure to select fifty six (56) infants who were aged between six (6) and twenty four (24) months for the study. The mothers of these 56 infants completed a sensory evaluation form to provide information on the acceptability to them of four complementary food (CF) formulations - GAD, PEA, KAN and SAB. The mothers served as surrogate respondents in the sensory evaluation of the developed products, instead of the infants, in accordance with the usual practice of care givers tasting food before serving it to their babies. In other words, it was posited that mothers could serve as substitutes for their children and as consumer sensory panellists for the complementary foods, as in previous studies [13, 14]. The sampling was done at the University of Cape Coast Hospital of babies who accessed the health facility for post natal care on a regular basis. The researchers requested for the attendance list of babies; and using random sampling, 100 babies were sampled. Out of one hundred (100) babies who regularly attended post natal care, forty (40) were babies above 24 months old. Therefore, they were not considered for the study since the researchers were testing the formulations on babies from six (6) to twenty four (24) months. Furthermore, on the day of the data collection, four (4) mothers opted out of the study on their own, since they were given the option to participate in the study or not.

2.4 Data Collection Instruments

The instrument for the data collection was developed by the researchers and it was reviewed by an expert in sensory evaluation. The developed questionnaire was used to elicit information on the acceptability or otherwise of the four formulations - GAD, PEA, KAN and SAB. Poir to data collection, the sensory evaluation questionnaire was pilot- tested using 10 panellists (infants with their mothers) in the Amanful community. The internal reliability of the sensory evaluation questionnaire, as measured by Cronbach's alpha coefficient, was 0.80 indicating a high internal correlation among the items. The content validity in meeting the objectives of the study was established with the help of the literature.

2.5 Ethical approval and Clearance for the Study

Ethical approval and clearance for the study were granted by the Institutional Review Board (IRB) of the University of Cape Coast (U.C.C) (Reference/Identification: UCCIRB/CES/2016/16). After approval had been obtained from the review board, all potential study participants (mother-child pairs) were individually approached to seek their consent to voluntarily participate in the study. The consenting process involved explaining the purpose of the study, confidentiality procedures, risks, benefits and the freedom to opt out of the study at any time without any penalty. Information was provided on the ingredients (the OFSP, anchovies, onion, and tomatoes) used in developing the CF products; and the prospective participants were cautioned not to volunteer to take part in the study if they were allergic to any of the ingredients.After the study had been thoroughly explained to the mothers, they were recruited to participate in the study after they had given their consent by either thumb printing or signing an informed consent form. To ensure respondents' data confidentiality, respondents were only identified with identity numbers.

2.6 Formulation of the three Complementary Food Products

2.6.1 Source of raw materials

Three blends of complementary foods made up of the orange fleshed sweet potato (OFSP), tomatoes, onion and anchovies were formulated on the basis of the quantities of the individual ingredients.The OFSP, locally referred to as the *Apomuden* variety was purchased from the Ministry of Food and Agriculture, Cape Coast, and was used as the major ingredient for all the complementary food formulations. The anchovies were bought from the Elmina beach. The tomatoes (*Bolga* variety) and onion (red onion variety) were bought from Kotokuraba market in Cape Coast. A commercial sweet potato-based CF (Cow and Gate brand coded as KAN), used as the control, was purchased from a supermarket in Cape Coast.

2.6.2 Development of the Orange Fleshed Sweet Potato Flour

The flow chart for the production of the sweet potato flour, as described by [15]was adopted and modified in the current study (Figure 1). Selected fresh tubers of the OFSP weighing 20 kg were washed thoroughly in water, peeled with a stainless steel knife, immersed in water to prevent discolouration and rewashed. The peeled tubers were grated into chips, using an ordinary grater. The chips were then spread thinly in a drying tray and dried in a hot air oven (Memmert model100-800) at 50 ^{0}C for 3 days. The dried chips were then milled into flour, using an electric mill (Panasonic mixer grinder, MX-AC 2015). The flour was then sifted with a fine sieve and packed into zip-lock bags and wrapped again in an opaque and impermeable package, as suggested by [16]. The developed OFSP flour was stored in a freezer for later use.

2.6.3 Preparation of Anchovy Powder

Selected fresh anchovies weighing 3 kg were washed in water. They were rewashed after the head and intestines had been removed. The prepared anchovies were spread in a drying tray and dried in a hot air oven (Memmert model100-800) at 50 ^{0}C for three (3) days. The dried anchovies were milled, using an electric mill (Panasonic mixer grinder, MX-AC 2015). The anchovy powder was sifted with a fine sieve and packed into zip-lock bags and stored in a cool dry place ready for use.

Flow Chart for the Production of the Orange Fleshed Sweet potato Flour

a) Sweet potato flour production Adeleke and Odedeji, 2010 [15] **b) Modified method for sweet potato flour production**.

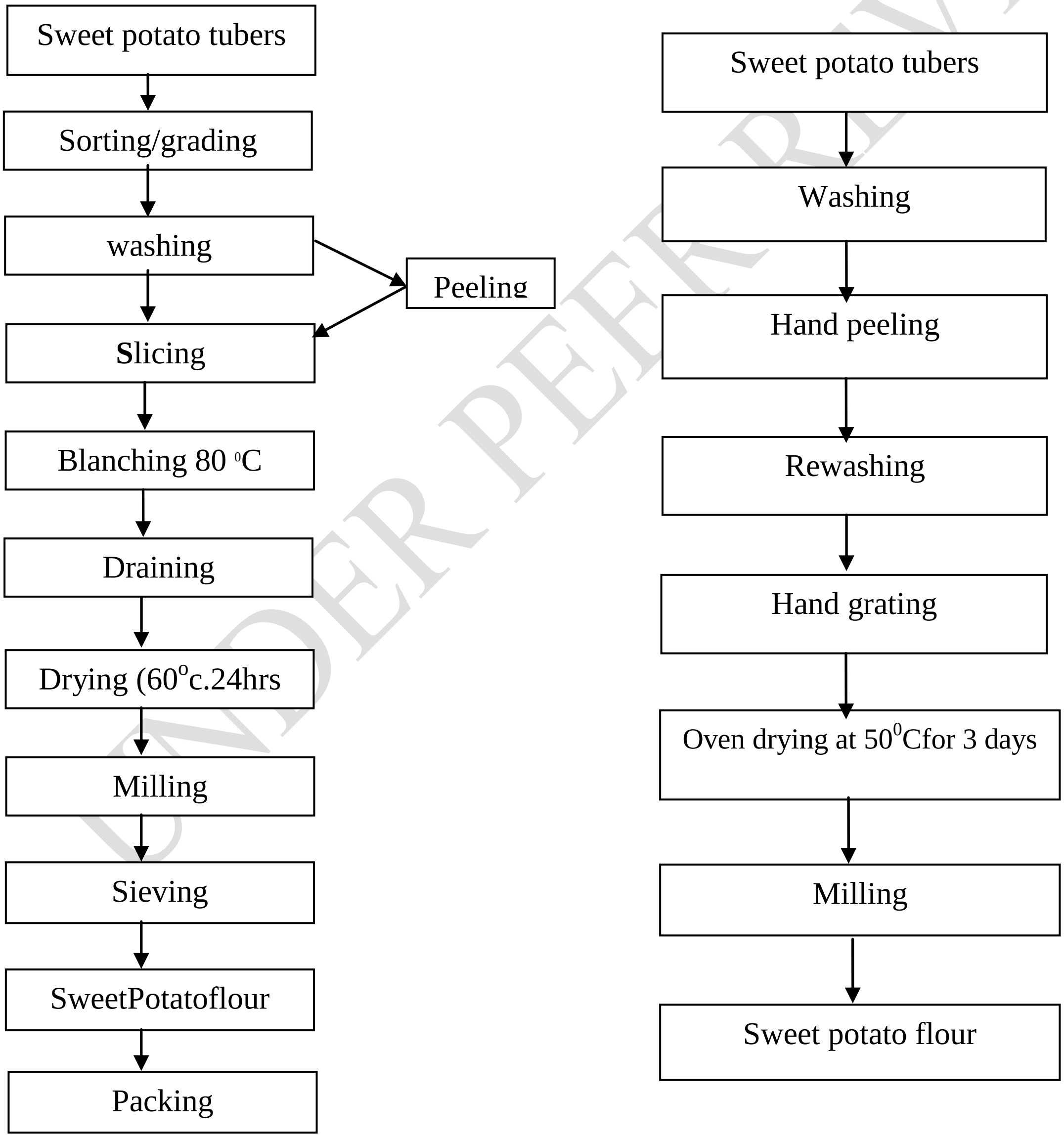

Figure 1: Flow Chart for the Production of the Orange-Fleshed Sweet Potato Flour

Source: Adeleke&Odedeji (2010)

2.6.4 Development of Onion Powder

The processes and stages involved in the development of the onion powder were conceived by the researchers. Selected fresh onions weighing 6 kg were peeled, washed and chopped using the nicer dicer manual chopping machine. The chopped onion was spread thinly in a drying tray and dried in a hot air oven (Memmert model100-800) at 50^{0}C for three (3) days. The dried onion was milled into powder, using an electric mill (Panasonic mixer grinder, MX-AC 2015). It was then sifted with a fine sieve and packed into zip-lock bags and stored in a freezer for later use.

2.6.5 Preparation of Tomato Powder

The processes involved in the development of tomato powder were based on modifications of the method described by Ashby (2005) as cited in Osae, 2014. Nine (9) kilograms of fresh and wholesome tomatoes (*Bolga* variety) were washed, blanched in boiling water for 3 minutes and then refreshened. The blanched tomatoes were then deskinned, deseeded and cut into quarters with a knife. The quarters of tomatoes were spread thinly on a drying tray and dried in a hot air oven (Memmert model100-800) at 50 ^{0}C for 3 days. The dried tomatoes were milled into powder, using an electric mill (Panasonic mixer grinder, MX-AC 2015). The powder was then sifted with a fine sieve and packed into zip-lock bags and stored in the freezer for later use.

2.7 Chemical Analysis of Samples and Formulated Formulas

The chemical composition of the food samples and the formulated formulas were determined according to the methods described by the Association of Official Analytical Chemists (AOAC), 2000 at the School of Agriculture laboratory of the University of Cape Coast. All the analyses were done in triplicates. For each of the food samples, the moisture content, protein, ash, fat, fibre and carbohydrate compositions were determined.The ß-carotene content of each formulated complementary food was determined, using the method described by [17].

2.8 Formulation of the Complementary Foods

The developed complementary foods were coded GAD, PEA and SAB and their various compositions are presented in Table 1. For each formulation, the quantities of the ingredients were based on ratios; and the ratios were varied to arrive at the best taste and aroma. The fact is that an increase of a particular ingredient in the formulation may make it a significant choice for a child, or rather, for his/her mother, since the mother of an infant may have greater influence in respect of the choice of food formulations to give her child.In addition, the protein, fat, fibre, carbohydrate, moisture and ash contents in the formulations were determined.

Table 1: Compositions of Formulations

Ingredients	GAD (200g)	PEA (200g)	SAB (200g)
Sweet potato flour	100g	125g	75g

Anchovy powder	50g	25g	75g
Tomato powder	25g	25g	25g
Onion powder	25g	25g	25g
Ratio	**4:2:1:1**	**5:1:1:1**	**3:3:1:1**

2.9 Sensory Analysis of the Developed formulations

The complementary foods were evaluated in terms of appearance, taste, texture, aroma and overall acceptability using a five- point hedonic scale (1=*Dislike very much*, 2=*Dislike moderately*, 3=*Neither like nor dislike*, 4=*Like moderately* and 5=*Like very much*) based on the reaction and facial expression of the babies. Each panellist was given a serving plate, 4 spoons and a cup of water to rinse their pallet in between tasting of the complementary foods sample and the coded complementary food samples in transparent cups. The glass of clean water was given to the participants to rinse their mouth before each determination to avoid discrepancies in taste.

3. RESULTS AND DISCUSSION

This study sought to formulate a complementary food (CF) product from the orange-fleshed sweet potato for infants. This section presents the results obtained from the chemical analysis of the formulated CF products, their functional properties and sensory attributes, and the discussion of findings.

3.1 Development of Complementary Foods for Infants

The complementary foods were formulated from a combination of different proportions of OFSP flour and powders from anchovy, tomato and onion. Each individual flour sample was analysed at the School of Agriculture Laboratory, University of Cape Coast.The proximate components (moisture, ash, protein, fat, fibre and carbohydrate) of each individual flour sample used in formulating the complementary foods are presented in Figure 2.

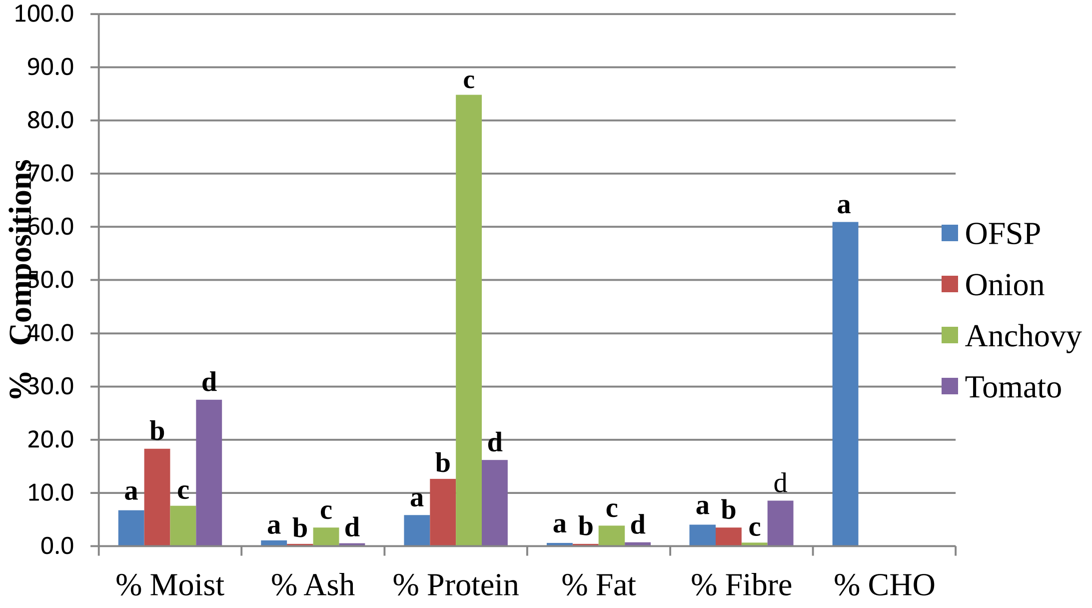

Figure 2: P*roximate components of flour samples*

OFSP – Orange-fleshed sweet potato flour

The results from the study showed that the anchovy used had the highest protein value of 84.8% amongst the ingredients. The proximate analysis (Figure 2) also revealed that protein was the highest nutrient identified in the anchovy powder. This was followed by carbohydrate, moisture, fibre, fat and ash respectively.There have been reports of differences in the protein content of anchovies when different methods were used in processing them. Abraha et al.(2017) [18] used solar tent to dry anchovies and found the protein content to be79.32%; but when they used an open sun rack, they found the protein content to be slightly lower(75.32%), suggesting some importance in the different methods used in producing the anchovy powder. However, tomato and onion powder had 16.2% and 12.7% of protein respectively. The protein content of the orange fleshed sweet potato flour (OFSP) was found to be rather low (5.9%) compared with the other ingredients probably because it is a starchy root.

The OFSP flour had a high (61%) carbohydrate content; and this characteristic of the OFSP flour was expected because it is a starchy root.Since complementary foods are expected to be energy dense [19], this attribute of the OFSP flour makes it a suitable ingredient for developing complementary foods.The carbohydrate percentage (61%) reported in this study was lower than those found by [20] and [21] which were 83.29% and 90.6% respectively.The difference in carbohydrate content as cited by [20] and [21] may be due to a difference in the variety of the sweet potato, the method of cultivation and the soil conditions under which the sweet potatoes were planted, as asserted by [22].The percentage of moisture recorded were relatively higher (27.5%) for tomato powder as shown in Figure 2.This was not surprising because tomato is a fleshy vegetable, known to have a high water content [23]. Onion powder had 18.35% moisture, while anchovy powder had 7.6%. The lowest moisture content of 6.9% was found in the OFSP flour.The value in this study was within the range reported by other researchers [16, 24, 25]. These authors reported a moisture content ranging between 2.50 and 13.2%. Similarly Dery (2012) [26] observed that the *Apomuden* OFSP variety used in this study contained the highest moisture content among the six varieties of sweet potatoes studied.This implies that the moisture content obtained in this study for OFSP flour was reasonably good.

The results from the fibre analysis revealed that tomato powder had the highest fibre content of 8.5% and that of the OFSP flour was 4.1%, followed by onion powder with 3.5%. The amount of fibre in anchovy powder was the least (0.7%), which was still lower than that found by [27].Opadotun, Adekeye, Ojukwu and Adewumi (2016) [28] reported of lower fibre content in tomatoes dried by sun and an oven. The sun dried tomatoes recorded a fibre content of 0.21%, whiles the oven dried one recorded 0.28%. The differences could be attributed to the difference in the methods of preparing the tomato powder and the variety of tomatoes used.

Ash content is considered very essential, as it is a measure of the mineral elements in a food sample [29]. In the current study, ash content was generally low; but, the anchovy powder exhibited the highest percentage (3.5%).Abraha et al. (2017) [18] found a higher ash percentage in their investigation which showed that ash content was 9.9% in solar tent-dried anchovy and 9.20% in the open sun rack-dried anchovy. Although the OFSP flour was prepared from a starchy root, it had 1.1% of ash, which was higher than that recorded from the tomato and onion powders -0.6% and 0.4% respectively.

As shown in Figure 2, the fat content of the anchovy powder was the highest (3.9%). This was followed by the tomato powder which had 0.7%, and the OFSP flour which had 0.6%. The least amount of fat (0.4%) was found in the onion powder. This value was similar to that reported for other varieties of onion bulbs from different origins [29]. According to

Aina et al.(2009) [25], the sweet potato,like other roots and tubers, is known to contain low fat, which implies that the flour produced from the OFSP in this study could be stored for a longer period of time without its going rancid, as reported by [30] .

The proximate analysis showed that the protein, ash and fat content of the anchovy were good enough to make it serve as an excellent source of high biological protein needed for growth in babies. The results obtained in the current study suggest that, blending the OFSP flour (as an energy food) with tomato (rich in moisture and fibre) and onion would make a nutritionally good complementary food, suitable for supporting the growth of infants.

3.2 Assessing the Chemical Constituents of the Formulated Complementary Foods

The chemical constituents (moisture, ash, protein, fat, fibre, carbohydrate and β carotene) of the formulated complementary foods are presented in Table 2.

Table 2 -*Chemical Constituents of the Complementary Food Samples*

	Chemical Constituents of Formulations						
Sample	**% Moisture**	**% Ash**	**% Protein**	**% Fat**	**% Fibre**	**% CHO**	**β-Caro-teneug/g**
SAB	12.62±0.08^{a}	5.62±0.18^{b}	44.04±0.8^{a}	2.35±0.11^{a}	4.02±0.04^{a}	36.65±0.47^{a}	90.21±0.55
GAD	12.33±0.02^{a}	5.68±0.08^{b}	31.97±0.5^{a}	1.99±0.14^{a}	4.14±0.5^{a}	35.54±1.08^{a}	142.2±0.57
PEA	12.89±0.15^{a}	5.58±0.13^{b}	21.83±0.8^{a}	1.24±0.01^{a}	5.39±0.21^{a}	49.22±1.39^{a}	134.26±1.28
KAN (Control)	85.47±0.15^{a}	0.56±0.03^{a}	13.80±0.23^{a}	5.41±0.20^{a}	6.08±0.06^{a}	43.81±0.53^{a}	77.89±0.28^{a}

-Source: Field data (2017)

a indicates significant whiles b indicates not significant

*Values are averages of triplicate determinations *Data is represented as mean ± standard deviation *Sample ratios are represented as (Orange-fleshed sweet potato: anchovy: onion: tomato) *Values in same column with same superscripts are significantly different at 95% confidence level

The developed complementary foods were coded GAD, PEA and SAB as presented in Table 1. The proportions of the ingredients were varied to determine the best taste and aroma as well as protein, fat, fibre, carbohydrate, moisture and ash present in the formulations. An increase of a particular ingredient in a formulation may make it a significant choice for a child, or rather, for his/her mother.It is important to note that the mother of an infant may have greater influence as regards the choice of food formulations to give her child.

The ratio used in formulating GAD was (4:2:1:1), meaning that 100g of the OFSP flour, 50g of anchovy powder, 25g of tomato powder and 25g of onion powder were weighed and mixed together to form GAD. The PEA(5:1:1:1) formulation was made up of 125g of the

OFSP flour, 25g of anchovy powder, 25g of tomato powder and 25g of onion powder; and the SAB(3:3:1:1) sample contained 75g of the OFSP flour, 75g of anchovy powder, 25g of tomato powder; and 25g of onion powder.

The moisture content of food samples, converted into their flour forms, usually determines their shelf life, and therefore, their storability. From the moisture content analysis shown in Table 1, PEA had the highest percentage of moisture, followed by SAB and GAD in that order. On the basis of the moisture content, the results that suggest that GAD could be stored for the longest period compared with the two (2) other formulations of complementary food, PEA and SAB.It must be noted that the moisture content recorded for all the three formulations (GAD, SAB, and PEA) were greater than the recommended moisture content in complementary foods of 5% and 10% suggested by the Protein Advisory Group [31] and the recommended moisture content (<5%) by Codex Alimentarius (1991) [32], on the basis of guidelines on formulated supplementary foods for older infants and young children.

Similarly, authors like Ojinnaka et al. (2013) [33] recorded a high moisture content of 11.55$\pm$0.20% to 16.51$\pm$0.03% in soya bean and cocoyam complementary foods they prepared. On the contrary, Mbaeyi-Nwaoha and Obetta, (2016) [34] recorded a lower moisture content ranging from 3.39±0.060% –4.78±0.090% in their millet, pigeon pea and seedless breadfruit leaf powder blends. Likewise, Fikiru et al (2017) [35] also found a moisture content ranging between 5.0 and 6.5% in a complementary food blended from malted barley, maize and roasted pea flour.

Although the moisture content was higher in this study, it was below the 14.5% level recommended by [36]which encourages microbial growth and could cause deterioration of the flour.According to Shahzadi et al. (2005) [37], flour products with moisture content less than 13% are more stable from moisture-dependent deterioration.The high moisture content recorded in this study may be attributed to the variety of sweet potato used and the drying technique used. Dery (2012) [26] also found *Apomuden* (theOFSP variety used) to be high in moisture content and thus difficult to process into flour.

The high ash content of the complementary foods that were analysed, suggests that the products could have high minerals content [38]. The ash values varied among the three (3) formulations (SAB, GAD & PEA). GAD had the highest proportion of ash followed by SAB; and the least ash percentage was found in PEA. The highest percentage of ash in GAD was rather unexpected, as the SAB formulation contained a higher proportion of anchovy powder compared with GAD.

The ash content observed in this study was higher than that reported in other studies [35, 38].The differences in the ash content between the current study and the previous ones could be attributed to the food ingredients used in preparing the complementary foods, the processing methods employed and even the storage conditions after their development. The ash content in all three (3) formulated complementary foods (GAD, PEA & SAB) in this study had mineral contents above the recommended value(<5 g/100 g) by the World Health Organization and Food and Agriculture Organization of the United Nations (WHO/FAO) (2004) [39] and the Protein Advisory Group (PAG) [31].

The protein content of the formulated complementary food products (SAB, GAD & PEA) varied.Clearly, the protein content of SAB was more, compared with the other two formulations, as shown in Table 1. However, a significant observation was that the protein content of SAB was more than twice that of PEA and than that of GAD, 12.07% more. That SAB contained the highest percentage of protein was expected, as the formulation contained more anchovy powder than in the other formulations (PEA and GAD).

The percentages recorded in this study were higher than what was reported in a previous study by [12],who found protein in the range of 12.1%-15% for their sweet potato based complementary food.Nandutu and Howell (2009) [40] also record a protein content of

20.4±0.1% and 28.0±0.4% in two complementary foods they developed from OFSP. The difference in percentages of protein may be attributed to the ingredients and their proportions used in the formulations of the OFSP-based complementary foods. According to the Protein Advisory Group [31], every complementary food should contain about 20% protein. From the results in Table 1, all the 3 formulations (SAB, GAD & PEA) had protein percentages higher than the recommended.

The protein content in the complementary food in the study by [12] was far below what was found in all the three (3) formulated samples (GAD, SAB and PEA) under consideration. This makes the developed complementary foods in the present study clearly high in protein; and they could be a source of providing essential nutrients to aid infants in their development. According to the World Health Organization (WHO) introducing babies between six (6) and 24 months of age to complementary food is very critical in their life because it is the period when malnutrition of all forms set in - stunting, wasting and underweight [41]. Babies should, therefore, be introduced to complementary foods which are high in energy and dense with protein [19].

The PEA formulation had the highest percentage of carbohydrate, and this was as expected since it contained the highest proportion of OFSP flour, compared with SAB and GAD which followed in that order.The results revealed that the carbohydrate content increased with an increasing quantity of the OFSP flour in the formulation, the OFSP being a root/tuber crop and a carbohydrate-based food.The carbohydrate content of the formulated CF products, within the range of 35.54±1.08% - 49.22 ±1.39%, is similar to results obtained in other studies [38, 42]. For instance, [38] recorded (30.10±0.01% -32.87±0.01%) carbohydrate content in a formulated CF product prepared from sorghum, soya bean and plantain. Similarly, [42] recorded 37.40±1.72% of carbohydrate in a formulated complementary food developed from wheat and groundnut.

Carbohydrate plays a very important role in complementary foods, since it is energy-dense and supplies the energy needed by infants for their rigorous crawling and numerous biochemical reactions. Other studies by [40] report higher carbohydrate 66.0± 0.2% and 58±1.4%; and [33] report which are higher still -percentages 78.55±0.12%-80.87±0.50% compared with the values recorded in this study. All the three (3) formulations of complementary foods in this study had carbohydrate content lower than the recommended by WHO/FAO [39] and PAG [31] for complementary foods (≥65g/100g). However, the findings in this study suggest that, increasing the proportion of OFSP flour could increase the carbohydrate content of the formulated complementary food.

The figures (78.55±0.12%-80.87±0.50%) recorded by [33] were far above the suggested figures prescribed by WHO/FAO [39] and PAG [31]. Excessive intake of carbohydrate from complementary food could be converted into fat and stored in the body, which gradually leads to infant obesity which increases their risk to diseases such as diabetes and hypertension later in life [43]. On the other hand, deficiency of carbohydrate in the body can cause the body to convert proteins and body fat to energy, thus leading to lessening of body tissues [44].

With regard to the fibre content, PEA had the highest value, followed by GAD with SAB containing the least amount.The high content of fibre in PEA could be attributed to the proportion of OFSP flour used in the formulation. The results therefore suggest that, the higher the amount of OFSP flour and tomato powder used in the formulation, the higher the fibre content.Two of the formulations (GAD and SAB) in this study met the recommendation by WHO/FAO [39] which indicates that the daily recommended allowance of fibre in complementary foods should be <5%. Although the fibre content in PEA exceeded the maximum content specified by the FAO/WHO standards, it may be more of a benefit than a nutritional limitation, as highlighted by [13]. This is because approximately 25-50% of the total fibre in sweet potato is soluble which improves digestive health and may serve as fermentable substrate for health-promoting colonic bacteria[45].The fibre content may encourage infants to eat more nutrient-dense food that may contribute to meeting their daily energy and other essential nutrient(s) requirements [46].Though fibre does not supply nutrients to the body, it adds bulk to food, thus facilitating bowel movements (peristalsis) and preventing gastrointestinal diseases [44]. Although a high intake of dietary fibre increases stool bulk, it however causes flatulence, and may fill up the small stomach of growing children, thus reducing their capacity to take in enough food to provide adequate nutrients and energy [19]. Abeshu et al (2016) [19], therefore recommended that low fibre foods may be more suitable for preparing complementary foods for infants and young children.

With respect to the fat content of the developed CF products, the highest percentage of fat was found in SAB which, perhaps, can be attributed to the higher proportion of anchovy powder in its formulation.This was followed by GAD,with PEA having the lowest percentage of fat. The results showed that the fat content increased with increasing the quantities ofanchovy fish powder added to the formulation. The percentages of fat recorded in other studies were 4.8%-6.4% [12], and 2.0±0.1% -3.4±0.5% [40]. The fat contents in these two previous studies were higher than in the present study.The present study found a fat content less than the recommended daily requirement for complementary foods ranging between 10% and 25% [39].Contrary to the findings in the present study,[47] obtained rather high percentages 15.6±0.2%-38.1±0.57%of fat in a formulated CF. It is worth noting that the amount of fat found in any formulated food sample can affect its shelf life.This is because high fat content foods have been found to undergo oxidative deterioration which leads to rancidification thereby making them more prone to spoilage than foods with a lower fat content [48].

The beta (β) carotene content of the formulated CF samples was highest in PEA, followed by GAD and SAB respectively.The higher content of β carotene in PEA may be attributed to the higher amount of OFSP flour in the formulation, since the flour contains β carotene. It can be deduced from the results of the analysis that the higher the proportions of OFSP flour in a formulated product, the higher its β carotene content.Theβ carotene content obtained in this study was higher than that reported by [20] in a sweet potato-based complementary food he prepared and by [12] in a study to enhance the nutritional composition of Ghanaian complementary foods. The different values ofβ carotene reported for the formulatedCFs in the various studies may be attributed to the variety of OFSP used, inclusion of other vitamin A rich food ingredients and the quantities of the ingredients that were used in the various studies.For instance, whereas in the present study the *apomuden* variety was used, [12] used *beauregard* OFSPand [20] used *bohye*.

According to [49] the suggested daily allowance of vitamin A for infants between 6 months and 3 years is between 350 and 400 µg.Although all the three (3) formulated complementary food samples (GAD, SAB & PEA) contained appreciable amounts of β carotene, they were below the range suggested as daily allowance of vitamin A for infants, perhaps suggesting the need to increase the proportion of the OFSP flour in the formulated CF products or to consider the possibility of including other vitamin A rich food sources, such as carrot and palm oil.

Table 1 also shows the chemical composition of the formulated samples (GAD, SAB & PEA) and of the sweet potato-based complementary food (KAN) which was used as the control. The results show that, generally, ash, protein and β carotene contents in the formulated samples - (5.58%-5.68%, 21.83%-44.04% and 90.21%-142.2% respectively) - were higher than the (0.56%, 13.80% and77.89% respectively) in KAN (control).

KAN (control) had higher values with respect to moisture, fat, fibre and carbohydrates 13.47%, 5.41%, 6.08% and 43.81% respectively, compared with the (12.33%-12.89%, 1.24%-2.35%, 4.02%-5.39% & 35.54%-49.22% for the formulated samples (GAD, SAB and PEA). The carbohydrate content of the formulated samples (GAD, SAB and PEA) ranged between 35.54% and 49.22% while KAN (control) had 43.81%, which was within the range of values for the formulated samples. It was observed that the carbohydrate content in the three formulations and the control (KAN) were far below the 65% for infant food as recommended by PAG [31].

The results further revealed that the ash content of the formulated samples were higher, which could be attributed to the high amount of anchovies used in the formulations. The formulated samples (GAD, SAB & PEA) were richer in minerals than KAN (control) in view of higher levels of ash in the samples. It was also observed that, because of the high amounts of anchovies used in the formulated samples (GAD, SAB & PEA) their protein content far exceeded that of KAN (control), in relation to the levels of protein in infant food (20%) recommended by PAG [31].

Therefore, the formulated samples (GAD, SAB & PEA) may enhance tissue repair and body building better than KAN (control) if taken by infants. The beta (β) carotene content in all the formulations (GAD, SAB & PEA) was higher, and this could be attributed to the variety of OFSP which was specially bred to contain high levels of vitamin A in order to support the normal functioning of the visual system and boost the immune system [50].

Determining the Functional Characteristics of theComplementary Food Products

The results of the analysis of the functional characteristics of the complementary food samples are shown in Table 3.

Table 3 -**FunctionalCharacteristics of theComplementary Food Samples**

Samples	**Bulk Density (g/ml)**	**SwellingPower (g/g)**	**Solubility Index (%)**	**WAC (%)**
GAD	.79±.00	8.01±.11	39.52±.35	330.97±.26
PEA	.78±.00	10.20±.31	37.13±.48	341.86±.64
SAB	.77±.00	9.04±.35	40.50±.14	308.98±.58

Source: Field data (2017)

*Values are averages of triplicate determinations *Data is represented as mean ± standard deviation

Bulk Density

Bulk density is a measure of the heaviness of the flour [51].Table 3 shows that SAB had the least value of bulk density amongst the formulated samples while GAD had the highest value of bulk density. The values recorded in this study were approximately equal to that reported by [20], but higher than that reported by [34] and lower than that recorded by [52].Okorie et al. [53] report that bulk density depends on the particle size of the commodites used, smaller particle size food items being associated with lower bulk density and vice versa. James et al. [51] report that lower bulk densities are considered best for a complementary food, as foods prepared from low density food items are easily digested by infants while retaining the nutrients.High bulk density reduces caloric and nutrient intake per feed of a child, which can result in growth faltering [52].From the results in Table 3,all the three (3) formulations (GAD, SAB & PEA) had lower bulk densities and hence suggest their suitability as complementary food formulas for infants.

Swelling Capacity

Swelling capacity was observed to be low amongst the formulated complementary food samples. PEA which had 125g of OFSP flour and 25g each of anchovy, onion and tomato powder had the highest swelling power. GAD with100g OFSP flour, 50g of anchovy powder and 25g each of onion and tomato powder had the least swelling power.The results in Table 3 showthat the samples could swell up to about ten (10) times their original size and weight.It has also been asserted that a lower swelling capacity of complementary foods is advantageous in feeding infants, as it increases the nutrient density of the food, thereby enabling the child to consume more in order to meet his/her nutrient requirement [51].On the other hand, complementary foods with high swelling capacity are not desirable because they may absorb more water and have less solid, resulting in a low nutrient-dense food [33]. This implies that, among the formulated complementary foods, PEA with the highest swelling capacity may produce a thick viscous porridge compared with GAD and SAB.

The high swelling capacity of PEA could probably be due to the high OFSP flour content.The swelling capacity values recorded in the present study were higher than those reported in previous related studies [20, 33]. However, researchers like [42] and [54] report higher swelling capacity values than as reported in this present study. Hence, the findings in this study that all the three (3) formulations (GAD, SAB and PEA) had low swelling capacity make them suitable complementary foods for feeding infants.

Solubility Index

The solubility of a protein is an essential functional attribute, as protein needs to be soluble in order to be relevant in food systems [51]. It can be deduced from the results in Table 3 that, the solubility indices of the formulations (GAD, SAB and PEA) increased with the proportion of anchovy powder in the CF produced.The values of solubility in this study were as expected since the formulations contained higher amount of protein as a result of adding anchovy fish powder.The solubility indices in the present study were higher than that reported by [20], probably because of the inclusion of anchovy fish, a high protein food source, which was not included in the CF formulations in the study by [20].

Water Absorption Capacity

According to [55], a lower water absorption capacity is desirable for producing thinner gruels or porridges with high caloric density per unit volume for supporting the growth of children. Victor (2014) [55] further explained that porridges of low water absorption capacity would allow addition of more solids, thereby increasing the quantity of total solids present in the CF.The water absorption capacity values varied amongst the three (3) formulations (GAD, SAB & PEA). SAB recorded the least water absorption capacity value, while PEA exhibited the highest.The water absorption capacity values increased as the quantity of OFSP flour increased

The water absorption capacity of the formulated complementary food samples was higher than as reported by [20] and [38]. However, Ghasemzadeh and Ghavidel (2011) [56] recorded higher values of water absorption capacities in their study which assessed the quality characteristics of cereal-legumes composite weaning foods.The difference in values reported in previous studies compared with the present study could be attributed to the different ingredients, varieties, processing and proportions of ingredients used.High water absorption capacity is unfavourable in complementary feeding as it limits the assimilation of nutrients [57].Therefore, of the three (3) formulated complementary foods, SAB with the least water absorption capacity may provide a more suitable nutrient- dense food to support the growth of infants.

Sensory Evaluation of the Complementary FoodAcceptability

The sensory characteristics of the complementary food samples are shown in Table 4. The samples were scored in terms of appearance, taste, texture, aroma and overall acceptability, using the five-point hedonic scale. The sensory analysis questionnaire was responded to by 56 randomly sampled infants (aided by their mothers) at the University of Cape Coast Hospital during their routine post natal visits.

Table 4-*Sensory Result of Formulated Complementary Food Products*

			Parameters		
Sample	**Appearance**	**Taste**	**Texture**	**Aroma**	**Overall acceptability**
KAN	4.36 ± 1.21	$3.57^{a}\pm1.36$	3.79 ± 1.29	$3.66^{a}\pm1.29$	$4.00^{a}\pm1.19$
GAD	3.39 ± 1.06	$3.21^{a}\pm1.45$	$3.71^{a}\pm1.17$	$3.66^{a}\pm1.07$	$3.66^{a}\pm1.28$
SAB	3.25 ± 1.03	$3.29^{a}\pm1.41$	$3.75^{a}\pm0.96$	$3.45^{a}\pm1.11$	$3.52^{a}\pm1.08$
PEA	3.55 ± 1.10	$3.41^{a}\pm1.57$	$4.14^{a}\pm4.12$	$3.54^{a}\pm1.21$	$3.64^{a}\pm1.17$

Source: Field data (2017)

N=56, [a]Mean values in column of the same superscript are not statistically significant at $p<0.05$

The overall acceptability mean score indicated that KAN (control) was the most accepted sample,as shown in Table 4. Appearance is an important characteristic considered when selecting and accepting food. The appearance scores for the samples showed that KAN (control) had the highest score, followed by PEA, GAD and SAB in that order. It is note worthy that the difference between KAN and PEA in terms of their mean score was 0.81, meaning that there was no significant difference at ($p<0.05$) in the appearance of the samples.

The taste of KAN (control) was rated highest compared with the rest of the samples;and GAD had the lowest rating taste. As shown in Table 4, the results of the taste anaylsis indicated that the difference between the mean scores of KAN and PEA was 0.16. This implies thatat ($p<0.05$) there was no significant difference in the taste of these products.

The mean score for texture was highest for PEA, followed by KAN (control), with GAD having the lowest mean score. The difference in the mean scores between PEA and KAN was 0.35,meaning that there was no significant difference at ($p<0.05$) between PEA and KAN.

The aroma ratings of the samples by the panellists were in the range 3.45 - 3.66. KAN, the control, and GAD, one of the formulated samples, had the highest aroma rating while SAB had the least aroma rating as shown in Table 4.The difference in the rating between GAD, KAN and PEA was 0.12, which implies that there was no significant difference ($p<0.05$) among the samples with respect to aroma.

The scores for the appearance of the complementary food samples increased with an increase in the concentration of the OFSP flour, perhaps as a result of the intensity and concentration of the orange colouration of the OFSP flour, which might have attracted the attention of the study participants. On the contrary, the scores for appearance of the formulated products decreased with an increase in the concentration of anchovy powder.The different ratios used in formulating the food samples contributed greatly to the different appearance and colour of the samples.The mothers of the infants reported that they preferred colourful foods.This is because babies are known to be easily attracted to bright colours. This is in line with a statement that colour and appearance are the initial quality features that attract people to a food product [58].According to Singh-Ackbarali and Maharaj (2014) [59], colour and appearance are indices of the inherent good quality of foods associated with their acceptability.With reference to appearance, two of the mothers liked the colour of KAN very much.

As noted above, KAN was rated the highest in respect of taste, although there was only a marginal rating value difference between KAN (3.57 $\pm$1.36) and PEA (3.41 $\pm$ 1.57). The taste score for PEA (close to that of KAN) may be attributed to the higher concentration of OFSP flour and a lower concentration of anchovy powder in the formulation, anchovy fish being known to have a strong smell and a unique taste.The implication is that a product may be appealing to the eye and have high energy density, but its taste and aroma may not be acceptable to consumer and they may reject it.

PEA which was rated closest to KAN was made up of 125g OFSP flour and 25g anchovy powder. It is likely that the higher OFSP flour concentration in the formulation imparted a sweeter taste and reduced the strong and pungent smell and taste of the anchovy fish powder in it, compared with GAD and SAB. Although KAN had the best rating for taste, two of the panellists liked the taste of all the formulated food samples except that of the control KAN.

The highest score assigned to PEA for texture acceptability may be attributed to the higher proportion of OFSP flour in it, compared with the other samples (GAD and SAB). Although PEA had the highest score for texture, some of the panellists complained about the rough nature of the formulated samples including PEA.This roughness may be attributed to the particle sizes of the flour which made it a bit coarse.Texture and mouth feel are connected, and mouth feel is considered a very important attribute in complementary foods because it determines the amount of food an infant would consume, since infants can swallow only smooth porridge foods and not coarse ones [33].

In terms of aroma ratings, both KAN and GAD had the same mean scores.The aroma rating of GAD may be due to the 1:2 proportion of anchovy powder (50g) to OFSP flour (100g) in its formulation. This might have produced a mild aroma which was pleasing to the mothers. The least score recorded for SAB with respect to aroma may be attributed to an increased quantity of anchovy fish powder in the formulation. SAB contained equal proportions of anchovy powder and OFSP flour, and the aroma of the anchovy powder might have been so strong in the formulation, thus affecting its aroma rating. Aroma is an integral part of taste for food before it is put in the mouth [58]. It is therefore an important parameter to consider in evaluating the acceptability of CF products that have been developed for infants. Although SAB had the least score for aroma, one of the mothers liked its aroma while two others rated itas poor.

The results as shown in Table 4 indicate that the overall acceptability score by the panellists was highest for KAN, followed by GAD, and then PEA; while SAB had the least overall acceptability score. KAN was accepted on the basis of the attributes (appearance, taste, texture and aroma) presented on the evaluation form. Probably, the appearance of KAN was most attractive, as babies by nature are attracted to bright colours.

Taste is detected by taste buds which are on the tip of the tongue and which help in determining taste. In tasting the food samples the panellists were provided with water to rinse their mouth after each sample test in order to remove all traces of the previous foods to prevent any form of bias. The results clearly showed that KAN had the highest mean value for taste among the samples.

Since the samples were presented randomly to the panellists, it could not be argued that KAN was probably placed at an advantageous position (either first or last in terms of arrangement of the positions of the four CF products). This implies that the panellists' choice of KAN as the best product was not influenced by its position during the sensory evaluation.

Conclusions

Compared with the control, the complementary foods developed from the orange fleshed sweet potato had lower moisture, fat and fibre content. They also had lower carbohydrate content, except PEA whose carbohydrate content exceeded that of the control by 5.41%. However, the protein, ash and β carotene contents were higher. The chemical anaylsis showed that the moisture content was highest in PEA and lowest in GAD; and the ash content was highest in GAD and lowest in PEA. The protein content of the samples was rather high; the highest being 44.04% (SAB) and the lowest (PEA) being 21.83%, compared with 13.80% for the control. The fat content ranged from 1.24% to 2.35% compared with 5.41% for the control. The fibre content was lowest in SAB (4.02%) and highest (5.39%) in PEA, compared with 6.08% in the control.The β carotene content ranged from 90.21 µg for SAB to 142.2 µg for GAD, compared with 77.89 µg for the control.

The functional properties of the developed complementary were good. Bulk densities ranged from 0.77 to 0.79g/ml; swelling power, from 8.01 to 10.20; solubility from 37.13 to 40.50%; and water absorption capacity, from 308.98% to 341.86%. Regarding the sensory evaluation of the products, panellists were found accepting the control more than the developed products. However, there was no significant difference between the developed complementary foods and the control in respect of the overall sensory acceptability which ranged from 3.52 for SAB to 4.00 for KAN (control).The most preferred complementary food was KAN, the control, followed by GAD which had 100g of the OFSP flour, 50g anchovy powder and 25g each of onion and tomato powder. This preferred formulated CF product (GAD)had the highest amount of β carotene - 134.26 µg.

The formulated complementary food samples can be used as a substitute for other locally produced foods for infants, as well as for KAN (control) which is a foreign product. The ingredients for the production of the new formulations (PEA, SAB & GAD) are locally available and affordable. As a result of their β carotene content, the new formulations (PEA, SAB and GAD) containing the OFSP (*Apomuden*) would help fight vitamin A deficiency disorders among infants. Caregivers could take advantage of the new formulations when they are produced in commercial quantities to supplement the local foods for infants. Alternatively, the methods that were employed in this study to develop the formulated CF products can be adopted at the household and community levels to produce nutrient- dense complementary foods to help address the menace of vitamin A deficiency disorders that confront infants in most developing countries.

Recommendations for Further Studies

Based on the findings of this study, some recommendations are made. First, there is the need to conduct studies on the microbial load of the formulated complementary food products. In addition, the shelf life of the formulated complementary food products should be studied. There is also the need to employ different drying methods to drythe food ingredients used in developing the CF formulations and study their effect on the nutritional composition, functional properties, shelf-life and sensory acceptablity of the food products.Also, a cost evaluation of the OFSP- based CF products should be conducted in comparison with other international products, such as Cow and Gate and Beech Nuts products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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