Development and characterization of instant nutrient dense amaranth-based composite soup for women of child bearing age

ABSTRACT

Aim: This study was aimed to develop nutrient dense instant grain amaranth-based soup with high protein, vitamin A, iron, zinc and dietary fibre contents for women of child bearing age using locally available crops in Uganda.
Study design: Six soups were produced from blends of extruded grain amaranth, groundnut, ROBA beans, pumpkin, orange fleshed sweet potato, carrot and maize flours in different proportions. The six formulations (soups) were tested for acceptability by panelists (n = 30) using the 9-point hedonic scale to obtain the most acceptable formulation. The most acceptable formulation was developed into an instant soup using extrusion cooking at barrel temperature of 169 ◦C and feed moisture of 14% to obtain an instant flour.
Place and duration of Study: Department of Food Technology and Nutrition, School of Food Technology, Nutrition & Bioengineering, Makerere University, Kampala, Uganda, between January 2014 and January 2015
Methodology: Sautéed and oven dried tomatoes, green pepper, ginger, garlic and other seasonings were milled coarsely and then incorporated into the instant powder to obtain the instant soup. The nutritional, physicochemical properties and consumers' acceptability of the instant soup were evaluated and compared with commonly used commercial soup.
Results: The formulated soup had a significantly higher nutrient density than the commercial soup. The instant soup had 11.83% protein, 4.9 mg/100g iron, 5.61 mg/100g zinc and 621.29 µgRAE/100g vitamin A. The sensory properties of the amaranth based instant soup revealed the soup was more liked over the commercial soup. Pasting properties showed that the amaranth based soup has better stability against retrogradation than the commercial soup.
Conclusion: Nutritious instant soup can be developed from amaranth-based flours.

Key words: Grain amaranth, women of child bearing age, extrusion cooking, instant soup, nutritional composition

1. INTRODUCTION

Women of reproductive age are at greater risk of under nutrition (protein-energy malnutrition and micronutrient deficiencies) than other adults because they are saddled with responsibilities such as child bearing and care, home keeping as well as income generation. Recurrent pregnancies, blood loss during menstruation also increase their nutritional and energy needs (Ho et al., 2016; Mousa et al., 2019). Other causes of maternal under nutrition can be attributed to poverty levels, limited diversity in diets, longer methods of food preparation and lack of fuel for adequate food preparation (Akande et al., 2017). As a result of these, it is of utmost necessity to develop ready-to-use, nutrient dense blended food products such as soup that will be easy to use and meet the nutrient needs of the targeted group.

Soup is a food product prepared by using different ingredients including pepper, tomatoes, onions, meat/fish, seasonings, spices and vegetables combined with other liquids or slurries; cooked together until an acceptable consistency, blend and desired taste are achieved. A good quality and reasonable proportion of soup depends on the variety and functional properties of supplemented ingredients (Abdel-Haleem and Omran, 2014). A soup with well-balanced nutrients can be obtained by including cereals, legumes, oils seeds, etc. As such the nutrient (carbohydrate, protein, dietary fibre, vitamin, mineral, amino acids) needs of the consumer will be met (Pandey et al., 2006). Also, functional ingredients can be easily incorporated into soup powders to provide health benefits (Ravindran and Matia-Merino, 2009). Cereal proteins are generally deficient in some essential amino acids. Animal proteins are also a major contributor to greenhouse gas emissions, deforestation and usage of water and can be expensive to include as part of soups for people in low income countries (Semba et al., 2021). To augment the protein quality of such foods as soups, the concept of complementation with a sustainable and underutilized crop such as grain amaranth that has a balanced protein profile can be adopted (Abdel-Haleem and Omran, 2014).

Grain amaranth has the potential to help reduce malnutrition and nutritional deficits since it grows quickly, produces a high yield, is stress-resistant, and nutritious (Muyonga et al., 2012). Amaranthuscruentus, a specie of the grain amaranth, has a high amount of sulphur-containing amino acids; methionine and cysteine that are deficient in legume grains and abundant in lysine that is deficient in cereals (Aderibigbe et al., 2022). The grains are also rich in unsaturated fatty acids (oleic and linoleic acids) (Mburu et al., 2012). According to Musa et al. (2011), grain amaranth spp contain critical vitamins that are of importance to women such as ascorbic acid, carotene, folate and pyridoxine. Grain amaranth also has higher levels of iron, zinc, magnesium, manganese, potassium and calcium than millet, sorghum, rice, wheat and corn (Gebhardt et al., 2008).

Although soup allows the combination of a variety of ingredients, the process of preparation of a nutritious soup is expensive, cumbersome and time consuming. Hence, development of functional, instant soup using cheap, readily available nutrient dense food crops such as grain amaranth, groundnut, pumpkin, ROBA beans, corn flours can help reduce food preparation time, increase diet diversity and also reduce the risk of protein energy malnutrition and micronutrient deficiencies associated with consumption of non-nutritious soups through the synergistic effects of nutrients from the different crops.
Formulation and development of several soup mixes have been developed using fish powder (Rahman et al., 2012), banana peel (Karthikeyan et al., 2015), de-bitteredMoringaoleifera seed flour (Radha et al., 2015), rice-based mix (Singh and Prasad, 2015), soy–mushroom–moringa (Farzana et al., 2017). However, development of soup using a pseudo-cereal such as grain amaranth as its base is not common despite its nutraceutical properties, balanced protein profile and ability to make up for other limiting amino acids in other cereals. Hence, this study developed instant amaranth-based soup and evaluated its nutritional, physicochemical properties and acceptability by comparing it with a commonly consumed commercial soup sold in Kampala City, Uganda.

2. MATERIAL AND METHODS

Groundnut, ROBA beans, pumpkin, orange-fleshed sweet potatoes (NASPOT-10), carrots, and maize, which are inexpensive, locally available, and complement the grain amaranth, were chosen because they are abundant providers of the desired nutrients (protein, iron, zinc and vitamin A).

2.1. MATERIALS

2.1.1. Raw materials

The *Amaranthus* grains, maize and ROBA beans flours were obtained from Nutreal Company, Kampala. Freshly harvested raw sweet potato cultivar NASPOT-10 was purchased from a farm in Bombo. The other ingredients such as carrots, groundnut, pumpkin, tomatoes, pepper, seasonings were sourced from Kalerwe market, Kampala, Uganda. The commercial soup was procured from a supermarket in Wandegeya. All purchasing sites were in Kampala, Uganda. All reagents used were of analytical grade.

The commercial soup

The commercial soup (Knorr soup) was made of wheat flour, salt, monosodium glutamate (flavour enhancer), sugar, hydrolysed vegetable protein (palm fruit, contains antioxidant TBHQ), radurised spices (coriander, cumin, cassia, methee, celery, fennel), dried vegetables (1 %) (Carrots, peas), radurised dried parsley, radurisedchillies, flavour enhancers (E631, E627), paprika oil, garlic powder, flavouring, colourants (E150d, E124, E110).

2.1.2. Preparation of flours

Raw groundnuts were sorted and milled using a local cast iron mill. The procedure of Dauthy (1995) was employed for the processing of the carrot and potato flour. The processing of the pumpkins was carried out according to the method of Pongjanta et al. (2006).

2.1.3. Formulations

Six nutrient dense formulations were created using Concept 4 creative software (Creative Formulation Concepts, LLC, Annapolis, MD, USA) (Table 1). The composite flours contributed the following: 30% energy, 45% vitamin A, 60% iron, and 70% zinc and 90% protein to the diet of women of child bearing age as recommended by Institute of Medicine of the National Academics (2006).

2.1.4. Sensory screening of the formulations

The six formulations (as predicted by Concept 4 software) with varying ratios of grain amaranth, carrot, OFSP and pumpkin flours and constant levels of ROBA beans, groundnut and maize were extruded using a DP70-III double screw inflating food machine (Jinan Eagle Machine Co. Ltd., Jinan, China). The extruded samples after cooling were pulverized using a 30 B-C milling machine (Changzhou Erbang Drying Equipment Co. Ltd., China) (Akande et al., 2017)

Each of the pulverized samples were prepared into six different soups by mixing 185 g of each of the composite flours in 750 ml of boiling water with constant stirring for about 4 min. The sauces were prepared as stated below (Development and preparation of instant soup with the processed composite flour). After which the prepared instant flour was turned into the sauce and allowed to simmer. After this preparation, sensory acceptability was determined by a semi trained panel (n = 30) mainly composed of students in the School of Food Technology, Nutrition, and Bio-engineering, Makerere University. A 9-point hedonic scale was used to score the acceptability of the soups. The most acceptable formulation was taken further for the instant soup flour development.

2.1.5. Development and preparation of instant soup with the processed composite flour

Fresh tomatoes (60 g), green pepper (20 g), fresh onions (40 g), ginger powder (1 g), garlic powder (2 g), curry powder (2 g), salt (10 g), groundnut oil (15 ml) and one cube (4 g) of beef seasoning (RoycoTM, Unilever, Kenya) were used for the preparation of the sauce. The oil was heated for a few seconds, the diced tomatoes, green pepper and onions were stirred into the heated oil, other condiments were added and the mixture sautéed for eight minutes. The prepared sauce was transferred into aluminum foil and dried in a cabinet dryer (Model no: B.MASTER, serial number SR 2046, TAURO, Italy) overnight at 65 °C. The dried sauce was then milled into coarse powder (using a kitchen blender) and mixed into 150 g of the extruded instant flour to obtain the amaranth based instant soup powder.

2.2. ANALYSES

2.2.1. Proximate analysis

The moisture, crude protein, ash, total fat, crude fibre, total carbohydrate and gross energy contents of the instant amaranth-based soup was determined using standard methods. Determination of moisture content was carried out overnight using the oven drying method at 98°C (AOAC (Association of Official Analytical Chemists) 1999); crude protein content was determined according to Kjeldahl procedure (AOAC, 2005); ash content by igniting the dried, instant ground soups in a furnace at 550 °C (AOAC, 2005); Soxtec apparatus was employed in the determination of fat content; crude fibre was determined using the acid and alkali digestion method as described by AOAC, 2005; gross energy of the soups was evaluated using the bomb calorimetry method and total carbohydrate was calculated as shown in equation 1.

On dry weight basis

$\%\,\mathrm{CHO} = 100\,\% - (\%\,\mathrm{Fat} + \%\,\mathrm{Ash} + \%\,\mathrm{Crude\ Fibre} + \%\,\mathrm{Crude\ Protein})$..Equation 1

2.2.2. Dietary fibre content

The dietary fibre content of the instant soup was determined using the FOSS FIBERTEC 2010. About 1.0 g of the sample was weighed into the crucible. The mixture for dietary fibre determination was prepared from cetyltrimethylammoniumbromide, concentrated sulphuric acid and distilled water (20g:28 mL:400 mL) and made up to 1000 mL with distilled water. The glass crucibles containing the samples were fixed into the FIBERTEC machine. The temperature was set at 50 °C and the mixture boiled for 45 minutes after which it was washed severally with distilled water. The glass crucibles were taken to the oven and maintained at 100 oC for 45 minutes to drive off the moisture. Dietary fibre was obtained as the difference between the weight of the empty glass crucible and that after removal from the oven.

2.2.3. Determination of mineral (iron and zinc) contents

Iron and zinc content were determined using the Savant atomic absorption spectrophotometer (GBC Scientific Equipment Pty Ltd. Dandenong, Victoria, Australia, Model: A.C.N 005472686) following the method described by Okalebo et al. (2002).

$$\mathrm{Concentration\ of\ Iron\ or\ Zn\ (mg/kg)} = \frac{(\mathrm{a}-\mathrm{b})\,\mathrm{x\ v\ x\ f\ x\ 1000}}{1000\ \mathrm{x\ w}} \ldots\ldots\ldots\ldots\ldots\ldots\ \mathrm{Equation\ 2}$$

Where a is the concentration of iron or zinc in the solution, b = Concentration of iron or zinc in the mean values of the blanks, v = final volume of the digest, f = Dilution factor and w = Weight (g) of sample.

2.2.4. Determination of Beta carotenoids content

The beta-carotenoid content was quantified using a method described by Bechoff et al. (2011). About 1 gram of the instant flour was weighed into mortar and homogenized with 50 mL of cold acetone. The sample was washed several times with the cold acetone until it was colourless. This was followed by filtering through a funnel plugged with a glass wool to remove the residue. The partitioning of the aqueous and organic phase containing the carotenoids was done with 30 mL petroleum ether in a 500 mL separating funnel with a Teflon stop-cock and acetone added. Distilled water (300 mL) was added slowly (letting it flow along the walls of the funnel) and carefully to avoid the formation of emulsions. After the two phases were formed, the lower phase (containing acetone and water) was discarded and the upper phase (mixture of petroleum ether and carotenoids) was washed four times with distilled water (200 mL) to remove the residual acetone. The petroleum ether (PE) phase was collected into a 50 mL volumetric flask. It was passed through a small funnel containing 15 g of anhydrous sodium sulfate to remove residual water. A piece of glass wool was plugged on the funnel to hold the anhydrous sodium sulfate in place. The separating funnel was washed with petroleum ether and the washings collected in the volumetric flask and topped up to volume (50 mL) with petroleum ether. The extracted total carotenoid was determined by taking the absorbance at 450 nm on a GENESYS spectrophotometer 10 ultraviolet (Thermo Electron Corporation, Marietta, Ohio). The carotenoid content was calculated as shown in equation 3.

Total carotenoid content (µg/g) = [(Ax V x 104)/ $A_{1cm}^{1\%}$ x W]…………………………..Equation 3

Where A is the absorbance, V is the volume of extract, $A_{1cm}^{1\%}$ is the absorption coefficient of beta carotene in petroleum ether (2592) and W is the weight (g) of sample

2.2.5. Consumer acceptability of the amaranth-based and commercial soups

The amaranth based instant soup was prepared by gradually mixing 185 g of the instant soup powder in hot water (750 mL) until the desired consistency was achieved. The commercial soup was prepared as specified by the manufacturer (60 g of soup in 850 ml of water). The soups were stored in different warmers for the acceptability test. The consumer acceptability test was carried out by 54 untrained panelists (for the instant soup and the commercial control) using a 9-point Hedonic scale (1= dislike extremely to 9 = like extremely). About 10 mL of each soups were presented to panelists in identical white small bowls, coded with 3-digit random numbers. Serving order was randomized for each panelist in individual sensory booths. Commercial bottled water was also provided to rinse the mouth before and between tasting samples. Panelists were asked to score the acceptability for colour, taste, flavor, mouth feel, consistency and overall acceptability. The amaranth-based soup was compared with a commercial soup (commonly used soup in Kampala city, Uganda).

2.2.6. Nutrient density determination

Varying concentrations (15%, 18%, 19% and 20%) of the instant amaranth soups were made by mixing with boiling water. The viscosity of the soups were established by measuring with a Brookfield DV II + Pro Viscometer at a temperature of 55 °C. The flour rate of the instant soups were determined until an appropriate viscosity (2500 - 3000 cP) (Mosha&Svanberg, 1983) was attained. After determining the flour rate that produced appropriate viscosity, the energy, protein, iron, zinc, and vitamin A content densities of each porridge and soup were computed using the flour rate.

$$\text{Nutrient density (100 mL)} = \frac{\text{Flour rate}}{\text{100 mL}} \text{ x } \frac{\text{Nutrient}}{\text{100 g}} \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 4}$$

2.2.7. Determination of pasting properties of the amaranth-based soups

The Rapid Visco Analyzer (RVA-4, Newport Scientific) was used in the determination of the pasting properties of the instant amaranth-based and commercial soups. The various viscosities (peak, setback, breakdown and final), pasting temperature and peak time were obtained with Thermocline for Windows software. The viscosities were given in Rapid Visco Units (RVU)

2.2.8. Statistical Data Analysis

The Statistical Package for Social Science (SPSS) software (version 17) was used for analyzing data for sensory qualities and pasting properties. The mean and standard deviation were computed. To determine significant differences in treatment means, the t-test and Analysis of Variance (ANOVA) were used, and the least significant difference technique was used for mean separation.

3. RESULTS AND DISCUSSION

3.1. Nutritional composition of the composite flours

Grain amaranth flour was combined with other flours to give six formulations that will contribute approximately 31 – 36% protein, 30 – 37 % iron, 12 – 28% vitamin A and 37 – 44% zinc and 19 – 23% energy to the daily recommended need of women of child bearing age without pregnancy (Institute of Medicine of the National Academics, 2006) (Table 1). This prediction was given by concept-4 software, a least cost formulation system.

The nutritional state of a woman before conception and during pregnancy is critical for both maternal and foetal health (Lundqvist et al., 2014). With proper dietary intake before and during pregnancy, the enormous burden of ailments for both mother and her offspring, with lifelong clinical and economic effects, can be avoided (Maffoni et al., 2017).

Protein is one of the pivotal nutrients required by a woman of child bearing age before, during and after pregnancy for proper growth and maintenance of the body. Protein is composed of amino acids. According to Watford and Wu (2018), amino acids are useful for the production of creatine, glucosamine, glutathione, hormones, neurotransmitters, nitric oxide, nucleotides, polyamines amongst others. When protein synthesis and degradation falls short, the synthesis of these compounds will be greatly affected. And as such inadequate consumption of protein by women of reproductive age can lead to debilitating conditions such as low birth weight, birth defects, increased susceptibility to diseases, stunting and fatality in severe cases (Vohr et al., 2017).

According to the National Health and Examination Survey carried out between 2011 and 2016, women of reproductive age (31 - 44 years) have insufficient intake of vitamin A in their diet (Murphy et al., 2022). Despite the abundance of pregnancy supplements, the problem of hidden hunger still persists. Hence, dietary interventions can still be a way of reducing the anomaly. Iron is also a key element before, during and after pregnancy. Body iron stores are vital before pregnancy because of the significant physiologic rise in the need for absorbed iron during pregnancy to expand the woman's red blood cell mass and to ensure an adequate iron supply for the operation of the placenta and the growing child (Milman et al., 2017). Low iron status may be partly attributed to low dietary iron intake (Milman, 2019).

Iron is required by practically all living creatures because it participates in several metabolic processes such as deoxyribonucleic acid (DNA) synthesis, electron transport and oxygen transfer (Abbaspour et al., 2014). Poor intake and impaired utilisation of iron by the body can lead to consequences ranging from anaemia to neurodegenerative diseases (Harika et al., 2017). Zinc deficiency however has been linked with adverse long-term effects on immunity, growth, and metabolic status of the surviving child. The predicted iron and zinc contents of the soups show the meal will meet more than three quarters the iron and zinc needs of a reproductive woman per 100 g. With higher flour rate for soup preparation, the daily needs for iron and zinc of a woman of child bearing age may be met.

Table 1. Formulations of amaranth based instant flours and their composition

F	Composition	Protein (%)	Energy/ 100g	Vitamin A (µg/100 g)	Iron (mg/ 100g)	Zinc (mg/ 100g)
1	(40GA:20B:G15:10C:15CF:0OF:0PF)	15.09	343.50	126.35	5.69	3.13
2	(40GA:20B:G15:10C:0CF:15OF:0PF)	15.19	350.25	107.45	5.73	3.13
3	(35GA:20B:G15:10C:0CF:0OF:20PF)	14.47	324.00	86.30	5.42	3.01
4	(45GA:20B:G15:10C:0CF:10OF:0PF)	16.71	391.50	172.25	6.60	3.46
5	(50GA:20B:G15:10C:0CF:15OF:0PF)	16.09	385.03	193.50	6.09	3.26
6	(40GA:20B:G15:10C:0CF:0OF:15PF)	16.40	387.67	136.10	6.71	3.55

GA: Grain amaranth; B: ROBA beans; G: Groundnut; C: Corn; CF: Corn flour; OF: Orange fresh sweet potato; PF: Pumpkin flour

3.2. Sensory evaluation results for the screening of the six amaranth based composite soups

Sensory attributes of a food product is one of key determinants in the acceptability of such a product. Sensory evaluation is an indispensable tool for obtaining feedback for making decisions and carrying out proper food product modification (Mihafu et al., 2020). The results for the screening of the amaranth based soup for acceptability is as presented in Table 2. From the results of the study, it was observed no significant difference in hedonic scores was detected for the samples in terms of consistency, suggesting that the soups were equally accepted in terms of consistency. Similarity in consistency can be attributed to the fact that the same flour rate was used in the preparation of the soups. The results for colour parameters showed only formulation with fresh OFSP was significantly different from all the soups. The aroma of the amaranth soups ranged from 6.0 – 7.4 with soups with fresh pumpkin and OFSP flour having the least and highest significant values, respectively. This indicates the aroma of the soup with OFSP flour was highly acceptable. On the average for all the sensory attributes, all the amaranth-based soups were liked moderately.

There were no significant differences ($P > 0.05$) in the mean overall acceptability scores of soup formulations 4 (with OFSP flour) and 6 (with pumpkin flour). However, soup formulation 6 had the highest mean overall acceptability score (7.6) while soup 2 (with fresh carrot) had the lowest mean score (6.6). The presence of dry OFSP and pumpkin flours may have enhanced the sensory acceptability of the former soups because of concentrated flavour, colour etc. Soup 6 was selected as the most acceptable formulation because it surpassed other soups significantly in terms of the overall appearance and overall acceptability. Overall appearance of a product is expected to stimulate the response of the consumer into developing expectations prior to consumption (Fioretini et al., 2020). A good mean score after evaluating the product is indicative of the fact that the expectations of the assessors were met.

3.3. Nutritional composition of the amaranth-based and commercial soup

Results of proximate composition, dietary fibre, iron and zinc contents of the instant soups are presented in Figure 1. The moisture content of the commercial soup shows it has more stability to moisture related deterioration. The high protein and fat contents of the amaranth soup can be attributed to the protein and fat contents of grain amaranth, groundnut and beans that were components of the instant soup. Previous researches have reported protein content of 16.62% for instant chickpea soup (Mohamed et al., 2020), 11.68% for instant oyster mushroom soup (Srivastava et al., 2019), 21.97% for instant ROBA beans sauce (Nkundabombi et al., 2015) amongst others. Differences in protein content of the instant soups can be attributed to the method of processing and principally the combination of ingredients.

The commercial soup had high ash content. Ash is usually regarded as an indication of minerals. The high mineral content of the commercial soup as indicated by its ash can be attributed to some of the components of the soups such as vegetables, spices, additives and salt. The dietary fibre content of the amaranth based instant soup was five times more than that of the commercial soup. The presence of flours of beans, maize, groundnut, pumpkin and grain amaranth may have contributed to high dietary fibre content of the resultant soup. According to Parmar et al. (2022) and Affrifah et al. (2021), raw groundnut and dry beans contribute 8.4 g/100 g and 11 g/ 100 g of dietary fibre, respectively. The combination of different spices and vegetables could have contributed to the high iron and zinc contents of the commercial soup. The results of the gross energy shows that amaranth based instant soup is a high energy soup when compared with the knorr soup. Amaranth soup also has higher vitamin A content when compared with the commercial soup. Pumpkin flour in the amaranth soup could be responsible for this.

Table 2. Sensory evaluation screening of the Amaranth-based composite soups on a 9-point hedonic scale

Formulations	Colour	Aroma	Texture	Consistency	Taste	After taste	Overall appearance	Overall acceptability
1	6.1 ± 1.54b	6.8 ± 1.1abc	6.9 ± 1.1ab	7.0 ± 1.0a	7.2 ± 1.1ab	7.0 ± 1.4ab	6.8 ± 0.8abc	6.8 ± 0.9bc
2	6.6 ± 1.9ab	6.2 ± 1.9bc	6.5 ± 1.5b	6.5 ± 1.7a	6.2 ± 2.0c	6.2 ± 1.9b	6.4 ± 1.8c	6.6 ± 1.7c
3	6.8 ± 1.8ab	6.0 ± 1.6c	6.7 ± 1.2ab	6.7 ± 1.3a	6.5 ± 1.6bc	6.4 ± 1.5ab	6.5 ± 1.4bc	6.9 ± 1.2abc
4	7.1 ± 0.9a	7.4 ± 1.1a	7.3 ± 0.9a	7.0 ± 1.3a	7.6 ± 0.9a	7.3 ± 1.3a	7.3 ± 0.9ab	7.6 ± 0.9ab
5	7.0 ± 1.2ab	6.9 ± 1.4abc	7.4 ± 0.7a	7.3 ± 1.4a	6.8 ± 1.4abc	6.9 ± 1.1ab	7.2 ± 1.0abc	7.1 ± 1.2abc
6	7.5 ± 1.5a	7.1 ± 1.3ab	7.4 ± 0.9a	7.2 ± 1.0a	7.2 ± 1.2abc	7.2 ± 1.3a	7.4 ± 1.4a	7.6 ± 1.1a

Values show mean ± SD (n=30) at 5% level of significance. Figures in a row with the same superscript are not significantly different

Formulations 2, 3, 4 and 6 have no carrots, 1, 3, 5 and 6 has no orange fleshed sweet potato and 1, 2, 4 and 5 has no pumpkin.

1 = Grain amaranth (40%), ROBA beans (20%), groundnut (15%), maize (10%) and fresh OFSP (15%);

2 = Grain amaranth (40%), ROBA beans (20%), groundnut (15%), maize (10%) and fresh carrot (15%);

3 = Grain amaranth (35%), ROBA beans (20%), groundnut (15%), maize (10%) and fresh pumpkin (20%);

4 = Grain amaranth (45%), ROBA beans (20%), groundnut (15%), maize (10%) and OFSP flour (10%);

5 = Grain amaranth (50%), ROBA beans (20%), groundnut (15%), maize (10%) and carrot flour (5%);

6 = Grain amaranth (40%), ROBA beans (20%), groundnut (15%), maize (10%) and pumpkin flour (15%)

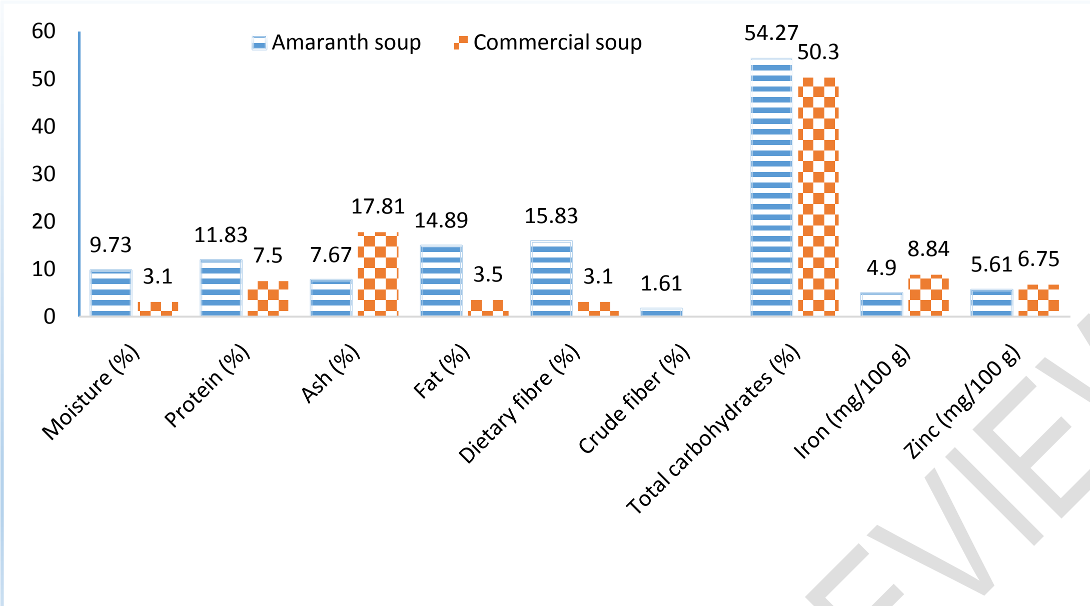

Fig. 1. Nutritional composition of the amaranth-based instant soup and commercial soups

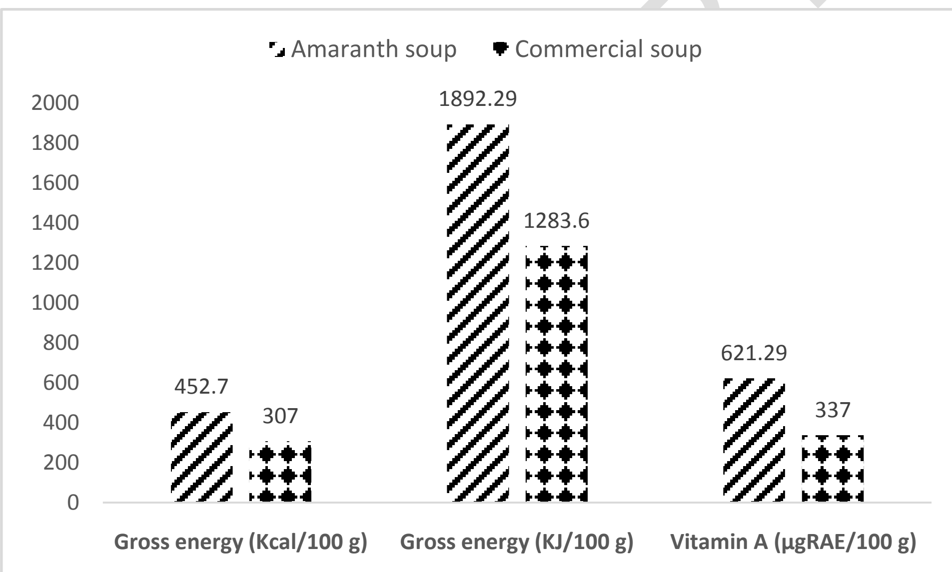

Fig. 2. Energy and vitamin A contents of the instant soups

3.4. Consumer acceptability of the soups

The consumer acceptability of the amaranth based instant soup and the commercial soup is as shown in Figure 3**.** The instant amaranth soup received significantly ($p < 0.05$) higher consumer acceptability scores than the commercial soup in terms of all the evaluated attributes. This may imply it had superior sensory quality attributes. The reconstituted soup was considered acceptable, with an overall acceptability score of 7.44. One of factors that could have been responsible for high scores of the amaranth soup is consumer's familiarity with some ingredients (groundnut, maize, pumpkin) used in the development of the soup. Both soups were, however, moderately liked.

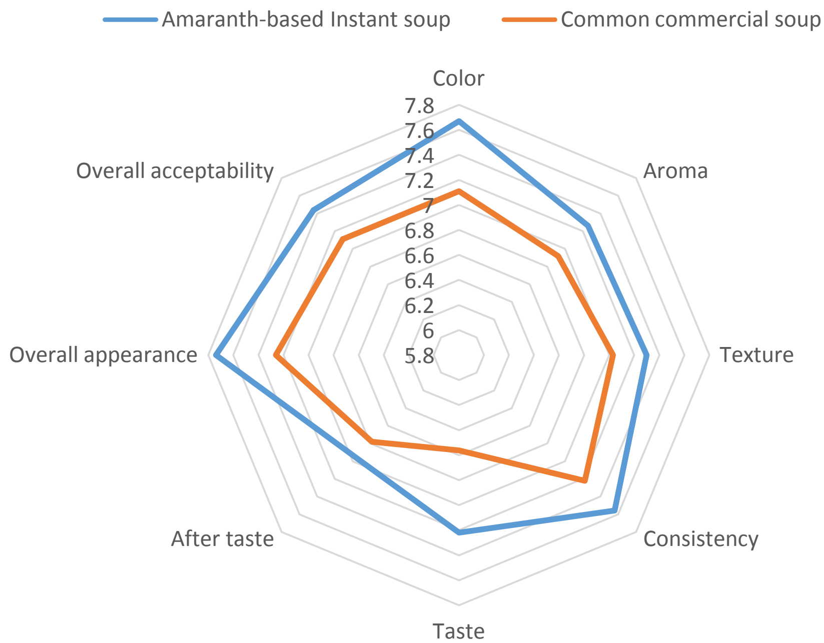

Fig. 3. Comparison of sensory acceptability scores for amaranth based instant soup and a commercial soup

3.5. Nutrient densities of the amaranth-based composite soup and the commercial control

The energy, protein, mineral (iron and zinc) and vitamin A densities of the soups are presented in Table 3. The amaranth-based instant soup had higher energy, protein, iron, zinc and vitamin A densities than the commercial soup. The amaranth-based instant soup when consumed once a day will meet give the stated amount of nutrients in Table 3 since 100 g of amaranth-based instant soup is required to make 400 mL of the soup and 28 g of the commercial soup is required to make 400 mL (based on manufacturer' specification). Clear differences obtained in the energy and nutrient density between the two soups as shown in Table 3 can be as a result of the flour rate used and nutrient complementation.

Table 3. Nutrient densities of 400 mL of the soup formulations

Nutrient	Amaranth-based instant soup	Commercial soup
Energy (Kcal)	446.72	86.68
Protein (g)	11.68	2.12
Iron (mg)	4.84	2.48
Zinc (mg)	5.52	1.92
Vitamin A (µgRAE)	613.08	95.16

3.6. Pasting properties of the amaranth based instant soup and the commercial control

Pasting properties of the amaranth based instant soup and control is as summarised in Table 4. Significant ($p < 0.05$) differences were observed in the pasting profiles of the soups. The commercial soup exhibited higher significant ($p < 0.05$) peak viscosity, trough, breakdown viscosity but lower significant ($p < 0.05$) peak time and pasting temperature than that of the amaranth based instant soup. The low breakdown viscosity of the amaranth based instant soup is an indication of its ability to withstand heating and shear stress (Ho *et al*., 2012). Final viscosity of the amaranth soup was lower which indicates the instant flour will form less viscous paste on cooling than the commercial soup. Low viscosity is beneficial because it will enable more soup to be consumed and hence more nutrients for the targeted women. Low setback viscosity of the amaranth soup reflects its tendency to be more stable against retrogradation than the commercial soup. The peak time is an indication of cooking time. The soups will require less than 100 ºC for preparation implying less energy use. Higher peak temperature of the amaranth based soup can be attributed to delayed swelling.

Table 4 Pasting properties of the formulated amaranth based soup and commercial soup

Pasting properties	Amaranth soup	Commercial soup
Peak viscosity (RVU)	7.88 ± 0.30[b]	84.29 ± 0.29[a]
Trough I (RVU)	7.25 ± 0.25[b]	46.50 ± 0.08[a]
Breakdown viscosity (RVU)	0.63 ± 0.05[b]	37.79 ± 0.21[a]
Final viscosity (RVU)	11.63 ± 0.46[b]	106.67 ± 0.33[a]
Setback I (RVU)	4.38 ± 0.21[b]	60.17 ± 0.42[a]
Setback II (RVU)	3.75± 0.17[b]	22.37 ± 0.63[a]
Peak time (minutes)	6.93 ± 0.00[a]	5.77 ± 0.04[b]
Pasting temperature (°C)	90.05 ± 0.05[a]	89.72 ± 0.03[b]

RVU- Rapid Visco Units. Values with different superscript letters along the rows are significantly different.

4. CONCLUSION

The study showed that acceptable nutrient dense instant soup can be developed from grain amaranth with other complementary crops. Amaranth-based instant soup can meet the daily protein, iron, zinc, vitamin A needs of women of child bearing age. The grain amaranth based soup had superior sensory quality than the commercial soup. The frequency of consumption of the soup will increase access to more protein, iron, zinc and vitamin A. The amaranth based instant soup showed a better pasting behavior than the commercial soup with its low viscosity and better stability against retrogradation.

REFERENCES

[1]. Ho A, Flynn, AC, Pasupathy D. Nutrition in pregnancy. ObstetGynaecolReprod Med. 2016;26(9): 259-264.

[2]. Mousa A, Naqash A, Lim S. Macronutrient and micronutrient intake during pregnancy: an overview of recent evidence. Nutrients. 2019; 11(2):443.

[3]. Akande OA, Nakimbugwe D, Mukisa IM. Optimization of extrusion conditions for the production of instant grain amaranth- based porridge flour. Food Sci. Nutr. 2017;5(6):1205-1214.

[4]. Abdel-Haleem AMH, Omran AA. Preparation of Dried Vegetarian Soup Supplemented with Some Legumes. Food Sci. Nutr. 2014;5:2274-2285. http://dx.doi.org/10.4236/fns.2014.522241

[5]. Pandey M, Anbidi AB, Siagh S, Singh RP. Nutritional Evaluation of Leafy Vegetable Paratha. J Hum Ecol. 2006; 19:155-156.

[6]. Ravindran G, Matia-Merino L. Starch-Fenugreek (*Trigonellafoenum-graecum* L.) Polysaccharide Interactions in Pure and Soup Systems. Food Hydrocoll. 2009;23:1047-1053. http://dx.doi.org/10.1016/j.foodhyd.2008.08.010

[7]. Semba RD, Ramsing R, Rahman N, Kraemer K, Bloem MW. Legumes as a sustainable source of protein in human diets. Glob. Food Sec. 2021; 28:100520.

[8]. Muyonga JH, Ugen M, Bisikwa J, Nakimbugwe D, Masinde D, Muyinda A. et al. Promoting Production And Utilization Of Grain Amaranth For Improved Nutrition And Health In: Uganda Annual Progress Report — Narrative And Appendices. 2012;1-100.

[9]. Aderibigbe OR., Ezekiel OO, Owolade SO, Korese JK, Sturm B, Hensel O. Exploring the potentials of underutilized grain amaranth (*Amaranthus spp*.) along the value chain for food and nutrition security: A review. Crit Rev Food SciNutr . 2022;62(3):656-669.

[10]. Mburu MW, Gikonyo NK, Kenji GM, Mwasaru AM. Nutritional and functional properties of a complementary food based on Kenyan amaranth grain (*Amaranthuscruentus*). AJFAND, 2012;12(2):5959-5977.

[11]. Musa A, Oladiran JA, Ezenwa MIS, Akanya HO, Ogbadoyi EO. Effect of heading on some micronutrients, antinutrients and toxic substances in Amaranthuscruentus grown in Minna, Niger State, Nigeria. Am. J. Food Nutr. 2011;1(4):147–54. doi: 10.5251/ajfn.2011.1.4.147.154.

[12]. Gebhardt S, Lemar L, Haytowitz D, Pehrsson P, Nickle M, Showell B, Thomas R, Exler J, Holden J. USDA national nutrient database for standard reference, release 21. United States Department of AgricultureAgricultural Research Service. 2006 Aug 6.Rahman, M.A., Saifullah, M and Islam, M.N. (2012). Fish powder in instant fish soup mix. J. Bangladesh Agril. Univ., 10(1): 145–148

[13]. Karthikeyan MS, Divakar S, Ukkuru P, Nirmala C, Kumari KS. Int. J. Curr. Res. 2015;7(08):19260-63.

[14]. Radha C, Ogunsina BS, HebinaBabu KT. Some quality and micro-structural characteristics of soup enriched with debitteredMoringaoleifera seeds flour. Am J Food Sci Technol. 2015;3(6):145-9.. DOI: 10.12691/ajfst-3-6-1

[15]. Singh Y, Prasad K. Sorption isotherms modeling approach of rice-based instant soup mix stored under controlled temperature and humidity. Cogent food agric. 2015;1(1):1103683. http://dx.doi.org/10.1080/23311932.2015.1103683

[16]. Farzana T, Mohajan S, Saha T, Hossain MN, Haque MZ. Formulation and nutritional evaluation of a healthy vegetable soup powder supplemented with soy flour, mushroom, and moringa leaf. Food Sci. Nutr. 2017;5(4):911-20.. DOI: 10.1002/fsn3.476

[17]. Dauthy ME. Fruit and vegetable processing. 1995. Accessed 7 August 2014. Available: http://www.fao.org/docrep/v5030e/v5030e0y.htm

[18]. Pongjanta J, Naulbunrang A, Kawngdang S, Manon T, Thepjaikat T. Utilization of pumpkin powder in bakery products. Songklanakarin J. Sci. Technology. 2006; 28:71-9.

[19]. Institute of Medicine of the National Academics. Dietary Reference Intakes: The Essential Guide to Nutrient Requirements. 2006. Accessed 9 April 2013 Available: http://www.nal.usda.gov/fnic/DRI/Essential_Guide/DRIEssentialGuideNutReq.pdf

[20]. AOAC. Official Methods of Analysis. 15th ed. Washington DC: Association of Official Analytical Chemists; 2005

[21]. AOAC. Official Methods of Analysis. 16th ed. Gaithersburg, USA: Association of Official Analytical Chemists; 1999

[22]. Okalebo JR, Gathua KW, Woomer PL. Laboratory methods of soil and plant analysis. 2nd ed. A working manual; 2002

[23]. Bechoff A, Poulaert M, Tomlins KI, Westby E, Menya G, Young S. et al. Retention and bioaccessibility of B-Carotene in blended foods containing orange-fleshed sweet potato flour. J. Agric. Food Chem. 2011;59(18):10373-80.

[24]. Mosha A, Svanberg U. Preparation of weaning foods with high nutrient density using flour of germinated cereals. Food Nutr Bull. 1983; 5:10 -14.

[25]. Lundqvist A, Johansson I, Wennberg A, Hultdin J, Högberg U, Hamberg K. et al. Reported dietary intake in early pregnant compared to non-pregnant women–a cross-sectional study. BMC pregnancy childbirth. 2014;14:1-10.

[26]. Maffoni S, De Giuseppe R, Stanford FC, Cena H. Folate status in women of childbearing age with obesity: a review. Nutr Res Rev. 2017; 30(2): 265-71.

[27]. Watford M, Wu G. Protein. AdvNutr. 2018;9(5):651-53.

[28]. Vohr BR, Poggi Davis E, Wanke CA, Krebs NF. Neurodevelopment: the impact of nutrition and inflammation during preconception and pregnancy in low-resource settings. Pediatrics. 2017;139(Supplement_1): S38-S49.

[29]. Murphy R, Marshall K, Zagorin S, Devarshi PP, Hazels Mitmesser S. Socioeconomic Inequalities Impact the Ability of Pregnant Women and Women of Childbearing Age to Consume Nutrients Needed for Neurodevelopment: An Analysis of NHANES 2007–2018. Nutrients. 2022;14(18):3823.

[30]. Milman N, Taylor CL, Merkel J, Brannon PM. Iron status in pregnant women and women of reproductive age in Europe. Am. J. Clin. Nutr. 2017;c1, 106 (suppl_6):1655S-62S.

[31]. Milman NT. Dietary iron intake in women of reproductive age in Europe: a review of 49 studies from 29 countries in the period 1993–2015. J NutrMetab. 2019;13.

[32]. Abbaspour N, Hurrell R, Kelishadi R. Review on iron and its importance for human health. J Res Med Sci. 2014;19(2):164.

[33]. Harika R, Faber M, Samuel F, Kimiywe J, Mulugeta A., Eilander A. Micronutrient status and dietary intake of iron, vitamin A, iodine, folate and zinc in women of reproductive age and pregnant women in Ethiopia, Kenya, Nigeria and South Africa: a systematic review of data from 2005 to 2015. Nutrients. 2017; 9(10):1096

[34]. Mihafu FD, Issa JY, Kamiyango MW. Implication of sensory evaluation and quality assessment in food product development: A review. Curr. Res. Nutr. Food Sci.. 2020;28(3):690-702.

[35]. Fiorentini M, Kinchla AJ, Nolden AA. Role of sensory evaluation in consumer acceptance of plant-based meat analogs and meat extenders: A scoping review. Foods. 2020; 22(9):1334.

[36]. Mohamed RS, Abozed SS, El-Damhougy S, Salama MF, Hussein MM. Efficiency of newly formulated functional instant soup mixtures as dietary supplements for elderly. Heliyon. 2020;6(1): e03197.

[37]. Srivastava A, Attri, B, Verma S. Development and evaluation of instant soup premix using oyster mushroom powder. Mushroom Res. 2019;28:65-69.

[38]. Nkundabombi M.G, Nakimbugwe D, Muyonga JH. (2016). Effect of processing methods on nutritional, sensory, and physicochemical characteristics of biofortified bean flour. Food Sci. Nutr. 2016;4(3):384-397.

[39]. Parmar S, Sharma V, Bomireddy D, Soni P, Joshi P, Gangurde SS et al. Recent advances in genetics, genomics, and breeding for nutritional quality in groundnut. Accelerated Plant Breeding. Oil Crops. 2022; 4:111-137.

[40]. Affrifah NS, Phillips RD, Saalia FK. Cowpeas: Nutritional profile, processing methods and products—A review. Legum. sci. 2022;4(3):e131. https:// doi.org/10.1002/leg3.131

[41]. Ho LH, Noor AA, Bhat R. Mineral composition and pasting properties of banana pseudo-stem flour from *Musa acuminata* X *balbisiana* cv. Awak grown locally in Perak, Malaysia. Int. Food Res. J. 2012;19(4):1479-1485.