Physicochemical properties and sensory evaluation of a bean-based composite soup flour

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Funding information
Food Security and Crisis Mitigation II, Grant/Award Number: EEM-G-00-04-00013; CGIAR, Grant/Award Number: BFS-G-11-00002

Abstract
A bean-based composite soup flour (CSF) containing red kidney beans, sweet potatoes, amaranth leaves, and carrots was developed using Nutrisurvey software to choose four nutritious CSFs, which were then subjected to sensory evaluation to select the most preferred CSF by mothers with young children. The top-ranked bean-based CSF was then analyzed for energy, proximate composition, and selected mineral/vitamin content. Additionally, swelling capacity, water and oil absorption capacity, emulsion activity/stability, foaming capacity/stability, gelatinization temperature, and least gelatinization concentration were determined. The optimum quality CSF was composed of 70% red kidney beans, 15% amaranth leaves, 10% sweet potatoes, and 5% carrots. The compositional and energy analysis showed that the selected CSF had 20.58% protein, 59% carbohydrates, 2.93% fat, 3.38% fiber, 8.95% moisture, 5.08% ash, and 344.9 kcal/100 g energy. The mineral and vitamins contents of CSF per 100 g were 216.2, 1.14, 3.83, and 32.83 mg for calcium, zinc, iron, and magnesium, respectively; 3.55 mg for vitamin A; and 166.36 mg vitamin C. Vitamins B2, B5, B6, B9, and B12 were 0.57, 3.53, 0.27, 0.07, and 0.02 mg/100 g, respectively. Functional properties determined were 31.5 ml (swelling capacity), 70.5% (water absorption capacity), 28% (oil absorption capacity), 25%, 18% (emulsion activity), 18% (emulsion stability), 15% (foam capacity), 33.4% (foam stability), 88.5°C (gelatinization temperature), and 10% (least gelatinization concentration). Consumption of the formulated CSF can nearly meet the dietary reference intake (DRI) of children aged 1–3 years in determined nutrients except for fiber. The developed bean-based CSF can be used to improve dietary diversity and reduce malnutrition especially for young children.

KEYWORDS
bean-based composite flour, functional properties, malnutrition, nutritional value

1 INTRODUCTION

Malnutrition in Rwanda among children under 5 years is a serious health and growth problem, where 35% are stunted, 2% wasted, and 12.6% underweight (Paridaens & Jayasinghe, 2018). Among the factors contributing to malnutrition are lack of dietary diversity, food insecurity, and significant postharvest losses of local produce (Weatherspoon et al., 2019). Appropriate nutritional intervention is...
therefore crucial to develop shelf-stable food products that are convenient, affordable, and nutrients-rich such as composite flours/meals. The intensive formulation and use of locally available food crops as a source of protein, energy, minerals, and vitamins will help to fight the problem of undernutrition and significantly reduce high postharvest losses (Teye et al., 2018).

Dry beans (Phaseolus spp.) are an appreciable source of carbohydrates, proteins, minerals, and vitamins, in terms of healthy and safe food supply particularly for poor populations (Celmeli et al., 2018). Rwanda is ranked first globally in per capita consumption of common beans. However, the capacity to process beans in the country in order to extend its consumption remains limited (MINAGRI, 2012). Red kidney bean flour is also a good source of nutrients, for example, protein, energy, calcium, and iron (Chaudhary & Sharma, 2013). However, red kidney beans are also reported to contain some antinutritional factors that inhibit proteolytic enzymes leading to reduced digestibility and protein absorption. Therefore, it is necessary to eliminate these antinutrients to enhance the bioavailability and digestibility for efficient use of proteins (Hayat et al., 2014). This can be achieved by applying some processing methods such as hot water blanching, soaking, dehulling, and cooking (Chaudhary & Sharma, 2013).

Sweet potato (Ipomoea batatas (L.) Lam.) tubers have high nutritional value (mainly carbohydrates) and good sensory attributes in terms of texture, taste, and flesh color (Truong et al., 2018). Rwanda is one of the major sweet potato producers in the East African Community, and it serves as family consumption and income with low inputs production. In order to extend their shelf life, sweet potato tubers are dehydrated (Padmaja et al., 2012). Leafy vegetables have gained commercial importance, they also form an important part of diet, providing micronutrients. As a result of their high moisture content and short shelf life, there is a need to process them so that they are available all the year round (Singh et al., 2014). Amaranth leaves (called dodo locally) are common leafy vegetables in Rwanda due to its nutritional importance (proteins, vitamins, and minerals) and affordability (Hakizimana & Maniragaba, 2019). Carrot (Daucus carota) is a delicious root plant, which besides providing high vitamin and minerals concentrations, is also a good source of some phytochemicals (Aderinola & Abaire, 2019).

Composite flours are prepared with a combination of various cereal and/or legume flours, which are rich in protein, starch, and other nutrients, with or without wheat flour. Locally grown crops require low production inputs; they are essential for agricultural diversification and can offer a unique opportunity to alleviate food and nutritional insecurity (Olaye & Ade-Omowaye, 2011). The use of composite flours has significant advantages for developing countries such as Rwanda in terms of promotion of indigenous plant species, better supply of protein for human nutrition; better use of domestic agricultural production, and motivation on the use of locally grown crops as flour (Noorfarahzilah et al., 2014). Ngorzi et al. (2018) formulated a weaning food from the blend of maize, plantain, and sesame seed flours, whereas Twum et al. (2015) developed a banana, soy bean, and maize composite flour. They were both developed based on the locally available raw materials that can contribute towards overcoming malnutrition and improving child nutrition.

The consumer acceptance of any newly developed product is dependent on the functional properties and sensory attributes; these define the behavior of ingredients during the preparation and cooking, as well as how the ingredients affect the finished products in terms of their appearance, texture, and tastes. Functional properties of food materials are very important for the appropriateness of diet, particularly, for the growing children to ensure optimum palatability and consistency (Tiencheu et al., 2016). The main objectives of this study were to develop a bean-based composite soup mix containing flours of red kidney beans, amaranth leaves, sweet potato tubers, and dried carrots. Proximate/nutritional composition and selected functional properties of the best bean-based soup mix, based on sensory evaluation, were also determined.

## 2 | MATERIALS AND METHODS

### 2.1 | Food materials

About 2 kg each of dry red kidney beans, fresh amaranth leaves, fresh sweet potato roots, and fresh carrots were purchased from local sources in Kigali City and Kabuga. Red kidney beans were cleaned to remove foreign matters and blanched in boiling water for 30 min, followed by three times rinse under tap water, and soaked overnight. The soaked beans were dehulled, then dried at 60°C in an oven for 10 h. Fresh sweet potato roots were peeled, thoroughly rinsed using tap water, sliced, and soaked in 1% vinegar for 10 min (to control enzymatic browning) and then dried in an oven at 60°C for 8 h. Amaranth leaves were rinsed three times in tap water, chopped, and blanched boiling water for 3 min. They were then dried at 55°C in an oven for 8 h. Carrots were peeled, rinsed thoroughly with tap water, sliced, and then blanched for 5 min in boiling water before drying at 60°C in an oven for 12 h. All the dried materials were ground in a commercial grinder and sieved through 60 mesh.

Raw materials to be used for sensory evaluation were dried in a commercial dryer (Natural Fruits Dryer Company Ltd in Nyagatare District, Eastern Province) and milled at Kabuga Mill to pass through 70-mesh screen.

### 2.2 | Composite soup flour (CFS) formulation

The CSF was formulated using Linear Programming Module of NutriSurvey where all the ingredients were analyzed by the Software based on the recommendations for children aged between 12 and 23 months. The best four nutritious formulations, as shown in Table 1, were selected for sensory evaluation. CSF quality comparisons were also made with nutritional labels of Shisha Kibondo, Sosoma 1, and Cerelac, which are weaning products sold at Rwandan market.
Table 1: Preliminary composite soup flour (CSF) formulations developed by linear programming using NutriSurvey

| Formulations | Red kidney beans (%) | Sweet potatoes (%) | Dried amaranth leaves (%) | Dried carrots (%) |
|--------------|---------------------|-------------------|---------------------------|------------------|
| CSF-A        | 60                  | 20                | 10                        | 10               |
| CSF-B        | 70                  | 10                | 15                        | 5                |
| CSF-C        | 50                  | 30                | 15                        | 5                |
| CSF-D        | 60                  | 30                | 5                         | 5                |

*CSF formulations were prepared using flours of red kidney beans, sweet potatoes, dried amaranth leaves, and dried carrots.

2.3 Sensory evaluation

After preliminary cooking trials, the soup for 30 participants was prepared using 150 g to be mixed in 1250 ml and cooked in 3750-ml boiled water for 5 min. Seven and a half (7.5) grams of salt were added while cooking. Thirty untrained women (literate and having one or more under 5 years' children) were chosen for sensory evaluation. The preference ranking test was conducted in order to classify randomly coded four CSF formulations from 1 to 4, starting with the most delicious SCF liked by young children. Participants were asked to taste the soups and rank them starting from the one they liked the most and mark it as number 1 up to the fourth one that is the least liked soup. Mothers were used rather than the targeted preschool children because mothers and children's food preferences are said to be somewhat related, and their acceptance of food can influence their children’s intake (Oduro-obeng & Plahar, 2017).

2.4 Nutrients' analysis of CSF

Based on sensory evaluation results, the first-ranked CSF was analyzed for nutrients at Rwanda Standards Board (RSB) chemistry laboratories. The water-soluble vitamins and vitamin A were determined at the International Livestock Research Institute (ILRI), Nairobi, Kenya, and the functional properties were determined at Kenya Industrial Research and Development Institute (KIRDI), Nairobi, Kenya.

The nutrients analysis was done based on the standard methods; all the instruments were calibrated before use, and each test was done in triplicate.

The formulated composite flour's nutrients content was converted to percentage dietary nutrients intake (DRI) using the following formula: % DRI = Nutrient content/DRI × 100 (Jeoung & Kim, 2021).

The considered DRI was for children between 1 and 3 years old.

2.4.1 Proximate analysis

Protein, fiber, ash, fat, and moisture content were determined by near infrared spectroscopy (NIR) (Foss DS2500, Höganäs) on the CSF. The cuvette filled with CSF was inserted into the sample compartment where it was illuminated with NIR radiation and the reflected radiation measured. The data were automatically processed and proximate composition displayed, according to the method of Osborne (2006).

Carbohydrate content on a wet weight basis (wb) was determined by difference (Ajifolokun et al., 2019):

\[
\text{Carbohydrates} \% = 100 - (\% \text{Protein} + \% \text{fat} + \% \text{fiber} + \% \text{ash} + \% \text{moisture})
\]

Energy value was calculated using the following formula (Bassey et al., 2013):

\[
\text{Gross energy (kcal/100g)} = (4 \times g \text{Protein}) + (4 \times g \text{Carbohydrate}) + (9 \times g \text{Fat})
\]

2.4.2 Mineral determination (Ca, Zn, Fe, and Mg)

Atomic absorption spectrometer (Analyst 800, PerkinElmer, Ohio) was used for calcium determination, following the method described by Poitevin et al. (2009). Flame atomic absorption spectroscopy (240FS AA, Agilent Technologies, Santa Clara) was used for zinc and iron determination, following the standard method (AOAC, 2005) number 999.10. The sample preparation was done by microwave digestion after adding concentrated HNO₃ and 30% H₂O₂, and then, the standard solutions were prepared. AAS was programmed depending on the elements to be analyzed, and multiple injections were done prior to taking readings and doing calculations to get the end results. Magnesium was determined by the EDTA method where the composite flour samples were incinerated and titrated with EDTA to find calcium plus magnesium and calcium value subtracted to remain with magnesium according to the procedure described by Kapadnis (2018).

2.4.3 Vitamins’ determination

Vitamin A was determined by HPLC (Shimadzu Nexera UPLC system linked to SPD-M2A detector). A reverse-phase gradient HPLC method was used. Oven for temperature control (OFF.YMC C30) and carotenoid column (3 μm, 150 × 3.0 mm, YMC Wilmington, NC) were used as described by (Bhatnagar-Panwar et al., 2013). Vitamin C was determined by HPLC, with Agilent 1260 system consisting of a UV-visible, fluorescence detector. The HPLC column used was a reversed-phase Discovery C18 (150 mm × 4.6 mm, 5 μm), according to the method of Ekinci and Kadakal (2005). Water-soluble vitamins were determined by UPLC (Nexera Liquid chromatograph LC-30AC with Phenomenex Discovery C18 (150 mm × 4.6 mm, 5 μm), according to the method of Ekinci and Kadakal (2005).
Synergi 2.6-μm polar C18– 100 mm × 3.00 mm, photo diode array detector), following the method described by Dionex (2010).

2.5 | Functional properties

The functional properties (swelling capacity [SC], water and oil absorption capacity [OAC], emulsion activity/stability, and foaming capacity/stability [FC/FS]) were determined according to methods described by Julianti et al. (2015).

2.6 | Statistical analysis

All the experiments were done using three replicates unless noted otherwise. Data analysis were done by analysis of variance (ANOVA), using SPSS version 16. Means were separated for statistical significance by Tukey’s method at \( p < 0.05 \). CSF quality comparisons were also made with nutritional labels of Shisha Kibondo, Sosoma 1, and Cerelac, which are weaning products sold at Rwandan market.

3 | RESULTS AND DISCUSSION

3.1 | Sensory evaluation

The sensory evaluation results from the preference ranking of four CSF formulations are presented in Figure 1. It should be noted that the sample with the lowest rank sum is the most preferred because the panelists were ranking from 1 to 4 starting with the soup they liked the most. Based on the low rank sum, mothers preferred the product CSF-B. This composite flour formulation had the highest amount of red kidney beans (70%), which most likely influenced the overall taste. These findings were expected given the fact that beans are most-liked among local populations and Rwandans have the highest per capita bean consumption in the world (Mulambu, 2017). The relatively higher protein (more beans) and lower carbohydrate (less sweet potatoes) of CSF-B makes it an ideal weaning food to address malnutrition and protein deficiency among young children. Therefore, the first-ranked CSF-B, composed of flours of 70% red kidney beans, 15% amaranth leaves, 10% sweet potatoes, and 5% carrots, was selected for detailed characterization of nutritional and functional properties.

3.2 | Proximate composition

The proximate composition of bean-based CSF is presented in Table 2. The CSF provided an excellent balance of proteins and carbohydrates, that is, relatively higher protein and lower carbohydrate content than cereal-based weaning foods.

3.2.1 | Protein

Protein content of the CSF formulated was the highest with 20.58% compared with other local weaning composite flours such as Shisha Kibondo and Sosoma 1 with 18% and 16%, respectively. As the legumes are quite rich in protein (18%–24%) (Noorfarahzilah et al., 2014), the big portion of red kidney beans (70%) with 21.48% of protein in the composite flour formulated (Kambabazi et al., 2021) corroborate the present results. Lower protein contents were previously reported (16.54%–18.57%) in different analyzed flour blends (wheat, rice, orange fleshed sweet potatoes [OFSP], and soybean) (Oduro-obeng & Plahar, 2017). A range of 9.2%–20.9% was also previously reported on a bean-based composite flour containing rice and amaranth grains at various ratios (Ndagire et al., 2015). The developed CSF’s protein content gave 158% of dietary reference intake (DRI) at 13 g per day (Institute of Medicine of the National Academies, 2011). Its contribution is higher than the DRI and is acceptable for malnourished children.

3.2.2 | Carbohydrate

Carbohydrate content of CSF was 59%. Wheat, rice, OFSP, and soybean blends contained 64.4% of carbohydrate (Ndagire et al., 2015), and wheat and maize blends contained 59.9%–65.8% carbohydrate (Ajifolokun et al., 2019). The differences between CSF and other composite flours/blends were likely due to different raw materials used. The developed CSF contribution to DRI (100 g/day) which is 59% is satisfying given that the child consumes other foods during the day. The high protein and carbohydrate content of CSF suggests that it
can be used in combating protein-energy malnutrition. Carbohydrates in CSF can provide energy to the body in order to spare protein, which can then be used for its primary function of muscles/body development to overcome stunting in young children (Awuchi, 2019).

3.2.3 | Fat

The fat content of CSF was 2.93%, which was higher than the 1.94%–2.57% range reported by Ajifolokun et al. (2019) for different ratios of wheat and maize blends and 2.2–2.84 reported by Raihan and Saini (2017) for oats, wheat, sorghum, and amaranth grains blends. However, significantly higher fat content was reported for local weaning foods such as Sosoma 1 and Shisha Kibondo with 15.8% and 10% fat, respectively, which can be explained by the higher fat content of soybeans and maize that were used in these commercial products.

3.2.4 | Fiber

The fiber content of 3.38% was higher than 2.27% reported in wheat-based flour containing chick pea, finger millet, and barley (Tangariya et al., 2018). This difference was possibly due to the main ingredient wheat which is a poor source of fiber. Among the local consumed weaning flours, Sosoma 1 contains 23% of dietary fiber, whereas Cerelac contains 3.2%. The latter is close to the present study’s results. The %DRI obtained (17.79%) is low and acceptable given that other foods consumed during the day also contain fiber. Too high dietary fiber content has been reported to impair protein and mineral digestion and absorption in human subjects. Hence, low-fiber diets are suitable for weaning foods. Fiber is an important dietary component in preventing overweight, constipation, cardiovascular disease, diabetes, and colon cancer (Tiencheu et al., 2016).

3.2.5 | Moisture content

The moisture content of CSF (8.95%) was close to 8.42% in Sosoma 1. Moisture content is one of the important parameters, which influences the shelf life or storage stability of flours. Flours > 14% moisture content are prone to mold growth and infestation by insects (Raihan & Saini, 2017).

3.2.6 | Ash

Minerals are essential in infants and young children for building bones and teeth; functioning of muscles and nerves; blood clotting; synthesis of hemoglobin, myoglobin, and enzymes/coenzymes; and enhancement of the body’s immune system thus reducing infections and fostering proper functioning of other organs of the body and for immune defense (Tiencheu et al., 2016). The ash content of CSF was 5.08%, which was similar to that reported by Tiencheu et al. (2016) for fermented maize, beans, fishmeal, pawpaw, and sugar different blend ratios. However, Sosoma 1 had lower ash content (3.31%) than that of CSF. The present findings revealed a high ash content, which implies the significant mineral concentration in the formulated CSF that can be attributed to 15% amaranth leaves with ash content of 24.3 g/100 g and 70% red kidney beans with 3.94 g/100 g ash content (Kambabazi et al., 2021). The Protein Advisory Group standard recommended that the ash content of weaning foods should not exceed 5%, but no standard for ash content has been specified for weaning foods in the Codex Alimentarius Standards.

3.2.7 | Energy

The CSF had energy value of 344.9 kcal/100 g, which was somewhat lower than that of Shisha Kibondo (400 kcal/100 g) and Sosoma 1 (443 kcal/100 g). The differences were most likely due to the presence of fat-rich ingredients in these commercial products. Twinomuhwezi et al. (2020) reported the energy value of 366.27 kcal/100 g in rice and millet blend. The present findings are in the same range as 341.96–363.82 kcal/100 g reported in fermented maize, beans, fishmeal, pawpaw, and sugar blends with various ratios (Tiencheu et al., 2016).

3.3 | Mineral content

The mineral content of CSF is presented in Table 3. Calcium content of CSF (216.20 mg/100 g) was within the 205.13–316.18 mg/100 g range reported by Tiencheu et al. (2016) for composite flour weaning food (CF-WF) consisting of fermented maize, beans, fishmeal, pawpaw, and sugar. Commercially available Sosoma 1 and fortified Shisha Kibondo had 30 mg and 788 mg/100 g calcium content, respectively.
The formulated CSF contributed up to 43.24% of the DRI of calcium (500 mg/day) (Institute of Medicine of the National Academies, 2011), which is not sufficient. However, the gap can be compensated by other calcium-rich foods consumed by the concerned children. Calcium plays a major role in the constitution of the skeleton and also in various metabolic functions such as muscle activity, nerve stimuli, enzymatic and hormonal activities, and oxygen transport (Nkeudem et al., 2018). The zinc content of CSF (1.14 mg/100 g) was within the range (0.91–2.27 mg/100 g) reported by Tiencheu et al. (2016) in CF-WF. The 38% DRI contributed by the developed CSF to 3 mg/day DRI is low, but the balance can be provided by other foods consumed by the concerned children. Zinc is especially important for the prevention of infections and to support the immune system as well as in growth, cognitive, and motor development (Oduro-obeng & Plahar, 2017). The iron content of CSF (3.83 mg/100 g) was higher than 2.86 mg/100 g reported for wheat, rice, soybean, and sweet potato composite flour (Oduro-obeng & Plahar, 2017), whereas 3.79 mg/100 g iron content of fermented popcorn-African locust-bambara groundnut blend (Ijarotimi & Keshinro, 2013) was similar to that of CSF in the present study. The 54.71% DRI iron in the formulated CSF based on 7 mg/day DRI of iron is adequate given that the children also consume other foods. Iron is an essential component of hemoglobin, an erythrocyte protein that transfers oxygen from the lungs to the tissues. Iron is necessary for growth, development, normal cellular functioning, and synthesis of some hormones and connective tissue (Jannat et al., 2017). Magnesium content of CSF (32.83 mg/100 g) was significantly higher than 2.86–4.98 mg/100 g reported for flour blends consisting of fermented popcorn-African locust bean blend, fermented popcorn-bambara groundnut blend, and fermented popcorn-African locust-bambara groundnut blend (Ijarotimi & Keshinro, 2013). However, CSF’s magnesium content was lower than 96.59 and 111.95 mg/100 g in CF-WF (Tiencheu et al., 2016). The Mg DRI is 80 mg/day and therefore 41.04% DRI is contributed by the formulated CSF, which is adequate as the rest can be obtained from the foods consumed by the children. Magnesium helps to maintain normal nerve and muscle function, supports a healthy immune system, keeps the heartbeat steady, and helps bones remain strong. It also helps regulate blood glucose levels and aid in the production of energy and protein (Kapadnis, 2018).

### 3.4 | Vitamin content

Vitamins A, C, B1, B2, B3, B5, B6, B9, and B12 contents were analyzed in the CSF developed. The results are shown in Table 3. Vitamin A is essential in the health of the cornea, gastrointestinal tract, skin, urinary tract, and lungs. This vitamin is essentially important in the prevention of night blindness and certain atherosclerosis conditions (Oduro-obeng & Plahar, 2017). Vitamin A content of CSF was 210 μg/100 g, which was lower than 450 to 5670 μg/100 g reported by Makanjuola and Adebowale (2020) in biscuits produced from wheat-cocoyam flour blends. The local fortified weaning flour Shisha Kibondo contains higher vitamin A (800 μg/100 g). The present product’s vitamin A content contributes up to 70.00% DRI, which is 300 μg/day. Consumption of the developed bean-based CSF could serve as a useful strategy to reduce vitamin A deficiency at risk people, like children and pregnant women in developing countries (Mukunda et al., 2021).

Vitamin C content of the formulated CSF was 166.36 mg/100 g. Farzana et al. (2017) reported lower values of 6.4 mg/100 g for soy–mushroom–morinda soup powder and 3.2–7.6 mg/100 g for different soup powders. Kosomata 1 also had lower values, Shisha Kibondo, and Cerelac had 60 mg/100 g and 70 mg/100 g vitamin C, respectively, whereas Makanjuola and Adebowale (2020) reported up to 78.92 mg/100 g in biscuits produced from wheat-cocoyam flour blends. The higher vitamin C content the bean-based CSF could be due to the presence of amaranth leaves, which is an excellent source of vitamin C (330.3 mg/100 g) as reported by Kambabazi et al. (2021).

When comparing the present study’s results to those for Shisha Kibondo, which is the local weaning flour blend composed of maize (56%), soya (20%), sugar (9%), skimmed milk powder (8%), and oil

### Table 3

| Mineral and vitamins | Content | DRIs: RDA and AI (1–3 years) | % DRI |
|----------------------|---------|-----------------------------|-------|
| Calcium              | 216.20 ± 4.33 | 500 mg/day | 43.24 |
| Zinc                 | 1.14 ± 0.012  | 3 mg/day  | 38   |
| Iron                 | 3.83 ± 0.55   | 7 mg/day  | 54.71 |
| Magnesium            | 32.83 ± 0.55  | 80 mg/day | 41.04 |
| Vitamin A (μg/100 g) | 210 ± 0.02   | 300 μg/day | 70.00 |
| Vitamin C            | 166.36 ± 3.90 | 15 mg/day | 1109.07 |
| Vitamin B2           | 0.57 ± 0.05   | 0.5 mg/day | 114   |
| Vitamin B5           | 3.53 ± 0.33   | 2 mg/day  | 176.5 |
| Vitamin B6           | 0.27 ± 0.01   | 0.5 mg/day | 54    |
| Vitamin B9           | 0.07 ± 0.00   | 150 μg/day | 46.67 |
| Vitamin B12          | 0.02 ± 0.02   | 0.9 μg/day | 2222.22 |

Note: Data are expressed as mean ± standard deviation (n = 3).

*Vitamins B1 and B3 were not detected.
(3%), it was found that all the B-vitamin values for Shisha Kibondo are lower than those of the bean-based CSF. This can be explained by the fact that beans are excellent sources of B-vitamins (Sparvoli et al., 2016). The contribution of the developed CSF to DRI is satisfying and sometimes higher than the DRI but can be attenuated by having a small serving size. Vitamin B2 helps to break down proteins, fat and carbohydrates and plays a vital role in maintaining the body’s energy supply. Vitamin B5 (pantothenic acid) is essential for carbohydrate and protein metabolism and is vital for growth and functioning of body cells (Makanjuola & Adebowale, 2020).

3.5 | Functional properties

The functional properties of CSF are presented in Table 4.

3.5.1 | Swelling capacity

The SC is an important factor used in determining the amount of water that food samples would absorb within a given time (Ijarotimi & Keshinro, 2013). In carbohydrate-rich food, it is evidence of the noncovalent bonding between the molecules within the granules of starch and also a factor of the amylopectin and α-amylase ratios (Awuchi, 2019). The SC of CSF was found to be 31.5 ml, which was similar to that of rice, millet, amaranth, and soybean flour composite reported by Twinomuhwezi et al. (2020).

3.5.2 | Water absorption capacity (WAC)

WAC indicates the volume of water required to form gruels with suitable consistency, for example, for infant feeding. Carbohydrates influence WAC of foods (Tiencheu et al., 2016). A high WAC is an important quality of an ingredient in food that needs hydration for textural and handling properties (Awuchi, 2019). In the present study, WAC of 70.5% was observed for CSF. Makanjuola and Adebowale (2020) reported a closer value of 66.5% for wheat and cocoyam composite flour, whereas Malomo et al. (2011) reported WAC of 60.50%–72.30% for a composite flour dough made of breadfruit, breadnut, and wheat, which were also in agreement with the present findings, whereas lower values between 5.79% and 7.17% were also reported on various flour blends (Twinomuhwezi et al., 2020). The ability of protein to bind water is indicative of its WAC. The higher WAC of CSF may prove useful in products where good viscosity is required such as soups and gravies (Chandra et al., 2015).

3.5.3 | Oil absorption capacity

OAC is a functional property that enhances the mouth feel while retaining the flavor of food products (Iwe et al., 2016). CSF had OAC value of 28%, and similar OAC values were reported by (Hasmadi et al., 2020): 29.59% (soybean flour), 35.08% (lara flour), and 35.70% (barinas flour). However, lower OAC values (5.89% to 7.72%) for different ratios of rice, millet, amaranth, and soybean flour composites were reported (Twinomuhwezi et al., 2020). Higher values (130 to 156%) were also previously reported (Chandra et al., 2015). Generally, the WACs of the weaning food formulations are systematically higher than their OAC, implying that weaning foods with high WACs tend to have low OACs due to the fact that there are more hydrophilic interactions in the weaning foods with high WACs (Tiencheu et al., 2016).

3.5.4 | Emulsion activity and stability

The emulsion activity is the ability of protein in foods responsible for emulsion formation as well as stability of freshly formed emulsion (Awuchi, 2019). CSF had 25% emulsion activity and 18% emulsion stability, Iwe et al. (2016) previously reported higher values: 42.50%, 56.78%, and 56.67% for rice, cowpea, and African yam bean flours, respectively. Emulsion activity with the values 39.05% to 43.88% for different ratios of rice, millet, amaranth, and soybean flour composites were reported (Twinomuhwezi et al., 2020). Generally, the emulsion stability of the weaning food formulations are systematically higher than their OAC, implying that weaning foods with high WACs tend to have low OACs due to the fact that there are more hydrophilic interactions in the weaning foods with high WACs (Tiencheu et al., 2016).

3.5.5 | Foaming capacity and foam stability

FC and FS are important quality parameters of flours. Proteins in flour are surface active, and soluble protein can reduce the surface tension; thus, the coalescence of the bubbles is obstructed. Protein molecules can unfold and interact with one another to form multilayer protein film with an increased flexibility at the air and liquid interface (Raihan & Saini, 2017). The CSF in the present study showed FC and FS of 15% FC and 33.4%, respectively. Our results are in agreement to FCs of 10.40% for cowpea and 18.17% for African yam bean flour reported by Iwe et al. (2016). Raihan and Saini (2017) also reported

| Functional property | Value |
|---------------------|-------|
| Swelling capacity (ml) | 31.5 ± 0.71 |
| Water absorption capacity (%) | 70.5 ± 2.12 |
| Oil absorption capacity (%) | 28 ± 1.41 |
| Emulsion activity (%) | 25 ± 0.00 |
| Emulsion stability (%) | 18 ± 1.41 |
| Foaming capacity (%) | 15 ± 1.41 |
| Foam stability (%) | 33.4 ± 0.09 |
| Gelatinization temperature (°C) | 88.5 ± 0.30 |
| Least gelation concentration (%) | 10 ± 0.00 |

Note: Data are expressed as mean ± standard deviation.
similar results for FC between 12.4% and 38.2% and FS between 23.33% and 58.33% in different blends of wheat, amaranth, sorghum, and oats grains.

3.5.6 Gelatinization temperature (GT)

GT is the temperature at which the gelatinization of starch takes place (Awuchi, 2019). Gelatinization is a process of breaking down intermolecular bonds of starch molecules in the presence of heat and water, allowing the hydrogen bonding sites to absorb more water. This causes the starch granule to irreversibly dissolve in the water. As soon as starch granules are heated in water, they absorb water, then swell and rupture, leading to increase in viscosity of the starch-water mixture. Finally, the mixture is thickened. The GT value obtained for CSF was 88.5°C. Chandra (2013) reported GT values between 57.58°C and 62.36°C for wheat, rice, green gram, and potato flours. The GT of starch depends on the plant type and the amount of water present, pH, salt concentration and types, sugar, protein, and fat in the recipe. Some types of unmodified native starches begin swelling at 55°C, and some other types at 85°C. The latter confirms the present study’s findings, and it shows that the CSF’s starch was not damaged significantly because the damaged starch granules swell faster (Awuchi et al., 2019).

3.5.7 Least gelation concentration (LGC)

LGC is used to measure the ability of the protein to form a gel (Hasmadi et al., 2020). The lower the level of the LGC, the higher the gelling ability of the protein ingredient (Awuchi, 2019). The LGC of CSF was 10%, which was similar to 10.5% reported for fermented popcorn-African locust-bambara groundnut blend (Ijarotimi & Keshinro, 2013). LGC of 10% to 16% has been reported for various legume flours (Noorfarahzilah et al., 2014). Based on the LGC value obtained in the present study, CSF may find useful applications in food systems such as sausage emulsions, custard type puddings, soups, and sauces, which require thickening and gelling (Hasmadi et al., 2020).

4 CONCLUSION

The formulated bean-based CSF is an excellent source of protein, carbohydrate, ash, calcium, iron, and vitamins A, C, and B complex and moderate in zinc and magnesium but poor in fat, fiber, and energy. The functional properties indicate that the bean-based CSF developed is intact and can give an excellent viscous, nutrient dense soup. The addition of carrots and amaranth leaves can enhance flavor and palatability of CSF as a weaning food. The nutritional value of the developed product suggests that it can be used to combat protein-energy malnutrition in the relatively lower energy content of CSF can be addressed by adding oil in the soup during preparation to raise oil content thus increase energy content. Consumption of the formulated CSF can meet a good proportion of and in some cases greater than the DRI for children aged 1–3 years in all the determined nutrients except for fiber. In cases where the contribution of the formulated composite flour to DRI is greater than 100%, it can be reduced by serving a smaller portion, and where the %DRI is less than 100%, the formulated composite flour soup can be supplemented with the other foods consumed by the child.

ACKNOWLEDGMENTS

This study is based on the work supported by the United States Agency for International Development (USAID), as part of the Feed the Future initiative, under the CGIAR Fund (Grant BFS-G-11-00002), and the predecessor fund the Food Security and Crisis Mitigation II (Grant EEM-G-00-04-00013).

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

M-R. Kambabazi conducted research work, analyzed data, and wrote the first draft; M. W. Okoth assisted with the project conceptualization, technical guidance, and editing of the manuscript; S. Ngala assisted with the project conceptualization, technical guidance, and editing of the manuscript; L. Njue assisted with the project conceptualization, technical guidance, and editing of the manuscript; and H. Vasanthakaalam assisted with the project conceptualization, technical guidance, and editing of the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Kambabazi, M.-R., Okoth, M. W., Ngala, S., Njue, L., & Vasanthakaalam, H. (2022). Physicochemical properties and sensory evaluation of a bean-based composite soup flour. Legume Science, 4(4), e139. https://doi.org/10.1002/leg3.139