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Addition of beans flour and Mukene (*Rastrineobola argentea*) powder improves the nutritional, sensory and functional properties of maize flour for porridge

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Abstract

Malnutrition is a burden among young children in Uganda due to inadequate intake of the required nutrients. Inadequate nutrient intake is partly caused by the use of plant based foods to wean infants. The plant based foods are high in calories but limited in other essential nutrients such as proteins, vitamins and minerals. This study aimed to develop maize-based composite flour enriched with locally available legumes namely; beans and soybeans and *Rastrineobola argentea* powder. Two formulations of maize-based composite flours with beans, soybeans and *Rastrineobola argentea* were made with one containing roasted beans and the other with unroasted beans. Flour blends were produced by mixing 55:20:20:5 (Maize: beans: soybeans: Mukene (*Rastrineobola argentea*) powder, w/w) while 100% maize flour was used as the control. The proximate composition results were: moisture content (5.03 to 5.32%), crude protein (10.11 to 19.00%), carbohydrate (63.17 to 79.60%), crude fat (3.96 to 4.52%) and crude fiber (2.10 to 4.40%). Energy content was between 332 and 377 kcal/100 g. Mineral content were: Calcium (14.80 to 1869.12 mg/100 g), Iron (1.45 to 58.97 mg/100 g). Functional properties results obtained were: water absorption capacity (150.71 to 305.00%), oil absorption capacity (86.01 to 200.00%), bulk density (0.63 to 0.83 g/ml), swelling power (2.6 to 7.8%), and solubility (0.5 to 19.0%). The substitution of maize flour with beans, soybean and *Rastrineobola argentea* had significant reduction in the overall sensory acceptability of porridge. Addition of beans, soy and *Rastrineobola argentea* powder flour resulted into maize based composite flour with high peak (490.33 to 839.33 cP), trough viscosity (467.00 to 803.33cP), set back (1124.00 to 1721.33cP) and final viscosities (1591.00 to 2524.67cP). Peak time (5.93 min) and pasting temperature (86.40 to 89.867 °C) of the composite flour were lower than those of maize flour (peak time; 6.93 min, pasting temperature; 93.67 °C). It was concluded that the addition of beans, soybeans flour and *Rastrineobola argentea* powder to maize flour enhanced the nutritional and functional properties of the composite flours. Therefore, the developed composite flour can be used in the management of undernutrition in developing countries.

Keywords Proximate composition · Minerals · Swelling power · Solubility · Acceptability · Pasting properties

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1 Background

Maize is a third staple after rice and wheat worldwide [1]. In Sub-Saharan Africa, maize is a food security crop for millions of people [2]. In Uganda, maize is a staple for most households both in the rural and urban [3]. It is consumed as thin or stiff porridges, boiled or roasted as snacks. Traditionally, maize is a major ingredient in complementary foods of young children. It is either used alone or as a composite of millet, sorghum, and wheat [4] or with legumes like soybeans, beans, peas. In Uganda, there is an increasing trend of mixing maize flour with animal protein sources like eggs, milk powder, Mukene (*Rastrineobola argentea*), Nkejje *(Haplochromines)* and cricket powder to enhance its protein content and improve protein quality [5, 6]. The most traded and consumed maize in Uganda is polished maize flour [7] which is regarded as nutritionally limited in lysine and tryptophan the essential amino acids and micronutrients such as calcium, zinc, iron sodium, selenium, vitamins A, B, C and E [8]. The poor nutritional quality of maize as a weaning food could be associated with the high levels of stunting (24.4%), wasting (3.2%) and underweight (9.7%) amongst children in Uganda [9]. Therefore, the nutritional value of complementary staple foods like maize can be improved using locally available foods.

Rastrineobola argentea is widely reported as cheap animal protein source ingredient used in complementary foods to improve protein quality and quantity. Ugada et al. [10] reported that *Rastrineobola argentea* has potential of complementing iron rich beans, and amaranth grains when formulated into micronutrient based flour that can be used to improve micronutrient intake of children 6–24 months. Similarly, Musabi [11] recommended using *Rastrineobola argentea* as protein supplements to populations largely dependent on cereal diets. Konyole et al. [12] reported that germinated grain amaranth and maize with or without edible termites and *Rastrineobola argentea* was acceptable among young children and mothers in Western Kenya. Besides, lysine and leucine are plentiful and always deficient in many staple cereal foods [13]. Additionally, *Rastrineobola argentea* is rich in iron (0.24 mg/g), calcium (38.08 mg/g), zinc (0.17 mg/g), sodium (3.76 mg/g), potassium (10.09 mg/g), magnesium (1.74 mg/g), and phosphorus (26.12 mg/g) [14]. *Rastrineobola argentea* also contain B group vitamins, particularly B12 [15]. Wessels et al. [15] revealed that utilization of *Rastrineobola argentea* contributes to the reduction of malnutrition and improved food security through provision of affordable nutrient dense animal sourced food to a wider population. Aderinola and Adeoye [16] revealed that the addition of beans flour to maize flour enhanced the nutritional and functional properties of the composite flours.

Addition of soybean and bean flours and *Rastrineobola argentea* powder to maize flour would increase the nutritional and functional properties of maize based composite flour. This makes the developed composite flour to be used in making porridge for young children. Children have small stomachs which accommodate small volumes of porridge [17] thus requiring porridge with low viscosity. This study focused on the solubility and swelling power of the developed composite flour because the solubility of flour is important in making paste while swelling power determines the viscosity of the porridge. Despite *Rastrineobola argentea's* potential as an excellent source of quality protein and minerals, it is still underutilized in combating undernutrition in Uganda. Thus, this study aimed at enhancing the nutritional composition of maize-based flour which is the main ingredient in complementary foods in Uganda by using *Rastrineobola argentea*, beans and soya bean flours.

2 Materials and methods

2.1 Selection of raw materials for use in this study

The raw materials that were used in this study were: maize grains, soybeans, *Phaseolus vulgaris L*. Yellow beans and *Rastrineobola argentea*. The raw materials were selected because they are rich in macro and micronutrients required by children aged 6–59 months. Their selection also was based on their nutrient quality especially *Rastrineobola argentea*. *Rastrineobola argentea* powder has high protein content (19.1 to 21.7%) with all/balanced essential amino acids especially methionine, total mineral content (10 to 14.58%) [18]. Maize has high calorie value and carbohydrate contents required for energy generation in the body. Roasted soybean was used to enhance the aroma of porridge in addition to its high protein content fiber. Yellow Beans (NAROBEAN 3) are high in protein (23.88%) but contain very low fat content (1.47%) [19]. Therefore, combining beans and soy in equal proportions would result in balanced protein product with low fat content and better sensory properties.

2.2 Source of raw materials and laboratory reagents

Maize, beans, soybeans and *Rastrineobola argentea* that were used in formulation of the composite flour were purchased from Kisenyi- Market, Kampala, Uganda. All the materials were delivered to the Laboratory at the Department of Food Technology and Nutrition, Makerere University for further processing. Laboratory reagents were supplied by Universal Laboratory Supplies, Kampala.

2.3 Pre-processing of maize, beans and soybeans

Maize, soybean and beans were separately sorted using the hand to remove foreign matter and those with defects. After sorting, maize was milled into flour using a locally fabricated hammer mill. The flour was packaged in a polythene bag and stored at 4 °C prior to mixing. A portion of beans and all soybeans were separately pan roasted at 100 °C for 20 min and later milled into flours using hammer mill. Flours were packaged and stored at 4 °C prior to mixing.

2.4 Determination of incorporation levels of ingredients used in the formulation of maize-based composite flour

Nutri-survey software version 2007 [20] was used to calculate the quantities of beans flour, soybeans flour and *Rastrineobola argentea* powder to add to maize flour. The target nutrients and their amount were the protein (13 g/day) and energy (1046 and 902 kcal/day for boys and girls, respectively) for the children aged 6–59 months [21]. The details of the combinations used to reach the required levels of each ingredient are presented in Table 1.

2.5 Determination of proximate composition of maize composite flours

Moisture content was determined as described by AOAC [22] by drying 5 g of each flour sample in a hot air oven at 100 °C for 16 h. Dietary fiber was determined following the method described by Nielsen [23]. About one gram of the sample was added to100 ml of acid detergent fiber and boiled for one hour in fiber analyzer. The digest was filtered through glass sinter crucible connected to a vacuum pump (Charles Austen pumps ltd, UK) and residues dried at 100 °C for 45 min. Total carbohydrates were determined using phenol–sulphuric acid method as described by Nielsen [23]. Protein content was estimated by Kjeldahl method as described by AOAC [22]. Crude fat was determined using the Soxhlet extraction method as described by AOAC [22] by adding 3 g of sample to 60 ml of petroleum ether (1268, Loba chemie laboratory reagents & fine chemicals) followed by boiling in Soxhlet equipment (Service unit Foss Ttecator, Sweden) at 100 °C for 15 min.

2.6 Determination of calcium and iron in maize composite flours

Calcium and iron as the most important essential minerals required by children, their concentrations in maize composite flours were measured by Atomic absorption spectrophotometer (AAS) according to the method of AOAC [22].

2.7 Determination of gross energy in maize composite flours

Total energy of maize based composite flour was determined based on the amounts of protein, fat and carbohydrate present in the sample using conversion factors proposed by the [24].

Table 1 Proportions of ingredients used in Nutri-survey to obtain maximum levels of target nutrients in the composite flour

Ingredient	Proportion (%)	Protein (g)
Maize flour	55	14.8
Soybean flour	20	
Beans flour	20	
Rastrineobola argentea powder	5	

$$\text{Energy (Kcal)} = 4 \times P + 4 \times C + 9 \times F$$

where P = Amount of protein in grams, C = Amount of carbohydrates in grams, F = Amount of fat in grams, 4 and 9 represent energy yielded by metabolizing 1 g of respective nutrient.

2.8 Determination of physical properties of maize-based composite flour

Water absorption, oil absorption, bulk density, swelling power and solubility properties of the composite flours were determined following methods of Tumwine et al. [5].

2.9 Pasting properties

Pasting characteristics of the porridge from the composite flour were determined with a Rapid Visco Analyzer (Perten Instruments AB, Kungens Kurva, Sweden) connected to a computer with thermocline for windows software [25]. The resultant viscosity was expressed in centipoises (cP).

2.10 Sensory evaluation of maize-based porridges

Fifty semi-trained consumer panellists rated the colour, taste, aroma, aftertaste, and overall acceptability of prepared porridges using a nine-point hedonic scale (like extremely = 9 to dislike extremely = 1).

2.11 Ethics statement

The protocol was approved by Clarke International University REC, in accordance with the relevant guidelines and regulations of the Uganda National Council for Science and Technology (UNCST).

2.12 Consent to participate in the study

Informed consent was obtained from participants to freely take part in sensory evaluation of provided porridges.

2.13 Statistical analysis

All determinations were done in duplicates and subjected to statistical Analysis of Variance (ANOVA) using XLSTAT software version 2024 to determine variation between means. Significance variation was accepted at $P < 0.05$.

3 Results and discussion

3.1 Proximate composition and energy of maize composite flours

Results of proximate composition and energy of maize composite flours are presented in Table 2. Generally, the moisture content of the samples was all below 10%. Maize-based composite flour with unroasted beans had highest moisture content (5.32%) followed by maize flour and that with roasted beans. There was no significant difference in the moisture content of all flours. Low moisture content in maize-based flour with roasted beans is attributed to the removal of moisture during roasting. Moisture content is important in the storage of dry foods because it affects the rate of deterioration and hence the quality of the product. The moisture content observed in this study is less than 14% that is recommended by Uganda National Bureau of Standards (UNBS) and lower than 8.77% that was reported by David et al. [26]. Thus, the developed composite flours will be shelf-stable.

Maize-based composite flour with unroasted beans had highest protein content (19.00%). A significant difference was observed between mean protein content of maize-based composite flour and maize flour. Low protein content in maize composite flour with roasted beans is due to roasting that result into protein denaturation and Maillard reactions. Aderinola and Adeoye [16] reported lower protein content (12.27%) in maize flour with 20% bean flour. This is because, in addition to the beans used in this study there was addition of *Rastrineobola argentea* (19–21%) [18] and soy bean flour

Table 2 Proximate composition (%), energy (kcal/100 g) of maize composite flours

Sample	Energy	Moisture	Protein	Carbohydrates	Fat	Fiber
Maize + soy + roasted beans + *Rastrineobola argentea*	370 ± 0.14^{b}	5.03 ± 0.38^{a}	18.58 ± 0.48^{a}	63.17 ± 0.20^{b}	4.46 ± 0.09^{a}	2.84 ± 0.14^{a}
Maize + soy + unroasted beans + *Rastrineobola argentea*	377 ± 0.64^{a}	5.32 ± 0.94^{a}	19.00 ± 1.16^{a}	65.29 ± 0.39^{a}	4.52 ± 0.27^{a}	2.10 ± 0.18^{b}
Maize	332 ± 0.78^{c}	5.09 ± 0.17^{a}	10.11 ± 0.13^{b}	79.60 ± 0.85^{c}	3.96 ± 0.21^{b}	4.40 ± 0.14^{c}

Values in the table are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts are significantly different

(35–40%) [27] that are also rich in proteins. Results from this study are in agreement with those of Kambabazi et al. [28] who reported high protein in bean-based composite soup flour.

Carbohydrate content was highest (79.6%) in maize flour and least (63.17%) in maize-based composite flour with roasted beans. Mean carbohydrate content was significantly different in all samples (Table 2). This was probably due to dilution effect and different processing conditions. The lowest carbohydrate in maize composite flour with roasted beans would be partly attributed to Maillard reactions. During roasting, carbohydrates in form of sugars, and amino acids, in particular lysine because of its free ∈-amino groups, undergo Maillard reactions, thus reducing protein and sugar contents of composite flours. Results for carbohydrate content of flours used in this study are in agreement with those of Aderinola and Adeoye [16] who reported 69.70% carbohydrate content in maize-beans composite flours. Addition of soy, beans and *Rastrineobola argentea* resulted into 50% increase in the fat content and 156% decrease in the fiber content of maize flour (Table 2). Higher fat content in composite flours is attributed to addition of soybean that is rich in oils (15–25%) [27] compared to maize (average 4.8%) [29] while reduced fiber content could be due to dilution effect.

Results for fat content are slightly higher than those reported by David et al. [26] who reported fat content of 3.64% in maize flour substituted with 20% soybean flour. The fat content in the composite flours is not significantly different because roasting only gradually reduces the moisture content of the grains. Fat, carbohydrates and protein are important in energy yield therefore, high energy content of maize composite flour with unroasted beans is due to high fat, carbohydrate and protein content. Roasting results into formation of resistant starch from amylose–lipid complexes and Maillard-reaction products due to high protein and reducing sugars which contributes to observed increase in dietary fibre in composite flour with roasted beans [30].

3.2 Mineral content of maize composite flours

The mineral content of maize-based composite flours is presented in Table 3. Addition of *Rastrineobola argentea*, beans and soybeans significantly increased calcium and iron content of maize flour. This is because *Rastrineobola argentea* is reported to contain high amounts of calcium (3600 mg/100 g) and iron (10.2 mg/100 g) [18]. Calcium (1869.12 mg/100 g) and iron (58.97 mg/100 g) were highest in maize composite with roasted beans could be due to breakdown of phytates in the testa of beans during roasting. Phytates always form complexes with nutrients such as Fe, Zn and Ca reducing their availability [31]. Results from this study are in agreement with those of Nakitto et al. [32] who reported an increase in minerals in roasted beans. Ugada et al. [10] reported that lower calcium (354 mg/100 g) and iron (19 mg/100 g) in the composite of *Rastrineobola argentea*, iron rich beans, and amaranth grains.

Table 3 Mineral content (mg/100 g) of maize composite flours

Sample	Calcium	Iron
Maize + soy + roasted beans + *Rastrineobola argentea*	1869.12 ± 0.25^{a}	58.97 ± 0.72^{a}
Maize + soy + unroasted beans + *Rastrineobola argentea*	1697.16 ± 0.49^{b}	58.04 ± 0.58^{a}
Maize	14.80 ± 0.28^{c}	1.45 ± 0.08^{b}

Values in the table are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts are significantly different

3.3 Physical properties of maize composite flours

Table 4 shows the physical properties of maize based composite flours. Oil absorption capacity (OAC) of composite flour ranged between 86.01 and 172.5% while water absorption capacity (WAC) was between 150.71 and 305.00%. The OAC of maize based composite flour was significantly ($p < 0.05$) lower than that of maize flour. The increased oil absorption capacity could be attributed to high protein content of *Rastrineobola argentea*, soy and beans flour which due to exposure of polar amino acids to the fat [33]. Findings from this study are in agreement with those of Tumwine et al. [5] who reported an increase in OAC of composite flours prepared by blending skimmed milk powder with millet flour and vegetable powders. High OAC is significant in retaining flavours in composite flours which increases mouth-feel because flour proteins physically bind fat by capillary attraction [34, 35]. The high WAC of maize-based composite flour is attributed to high protein content from blending of *Rastrineobola argentea*, soy and beans. Protein increases hydrogen bonding that allows water binding. The high water absorption capacity of composite flours facilitates solubility in water which is important in porridge preparation. Incorporation of beans, soybeans flours and *Rastrineobola argentea* powder increased the bulk density of maize composite flour. This could be attributed to the heavy weight of the added powders in comparison to maize flour. Interestingly, Edema et al. [36] reported a decrease in bulk density of maize with increasing soy supplementation. This is probably because of the high weight of soy flour.

The bulk density increased (0.63 to 0.83 g/ml) on addition of beans, *Rastrineobola argentea* and soybean flours. High bulk density of composite flours is probably due to heavier weights of soy and beans flours added. In addition, unroasted beans flour is heavier than roasted flour which contributed to the highest bulk density in composite flour with unroasted beans. Results for bulk density from this study are lower than for those reported by David et al. [26] who reported the bulk density of 0.9 g/ml in maize-based composite flour with 20% soybean flour. Sahu & Patel [37] also reported lower bulk densities (0.14 to 0.26 g/ml) in maize–millet based soy fortified composite flours. The observed low bulk densities of maize flour suggest that it is suitable for use in high nutrient density foods.

3.4 Functional properties of maize-based composite flours

3.4.1 Solubility

Figure 1 shows solubility of maize based composite flours. Results indicated that at any temperature, the solubility of the maize based composite flour with unroasted beans was higher than that of maize flour with roasted beans. The higher solubility of maize based composite flour with unroasted beans is attributed to higher sugar and high protein content than that with roasted beans (Table 2). Similarly, maize flour had highest solubility due to highest sugar content. Results further indicated that for every increase in temperature, the solubility of flours increased from 0.5 to 19.0% for maize flour, 0.7 to 17% for maize flour with unroasted beans and 0.3 to 14% for maize flour with roasted beans. Solubility was low for all samples at temperatures below 50 °C but gradually increased between 50 and 70 °C. A sharp increase in solubility of flours was observed between 70 °C and 80 °C (Fig. 1). At 80 °C, maize flour had highest solubility (19%), followed by composite with unroasted beans (17%) and then that with roasted beans (14%). Solubility of flour refers to its ability to dissolve in a liquid and it is influenced by pH, temperature, and the presence of salts. At higher temperatures, starch granules absorb water, swell and eventually rapture which results into leaching of amylose molecules into water [38]. Leaching of amylose in water exposes its molecules that form hydrogen bonds with water facilitating solubility of starch. Therefore, high sugar content in maize and maize-based

Table 4 Physical properties of maize composite flours

Sample	Water absorption capacity (%)	Oil absorption capacity (%)	Bulk density (g/ml)
Maize + soy + roasted beans + *Rastrineobola argentea*	150.71 ± 0.14^{c}	172.50 ± 0.00^{b}	0.71 ± 0.10^{b}
Maize + soy + unroasted beans + *Rastrineobola argentea*	305.00 ± 0.07^{a}	86.01 ± 0.05^{c}	0.83 ± 0.00^{a}
Maize flour	270.00 ± 0.28^{b}	200.00 ± 0.01^{a}	0.63 ± 0.02^{c}

Values in the table are means ± standard deviations of triplicate determinations. Means in the same column with different superscripts are significantly different

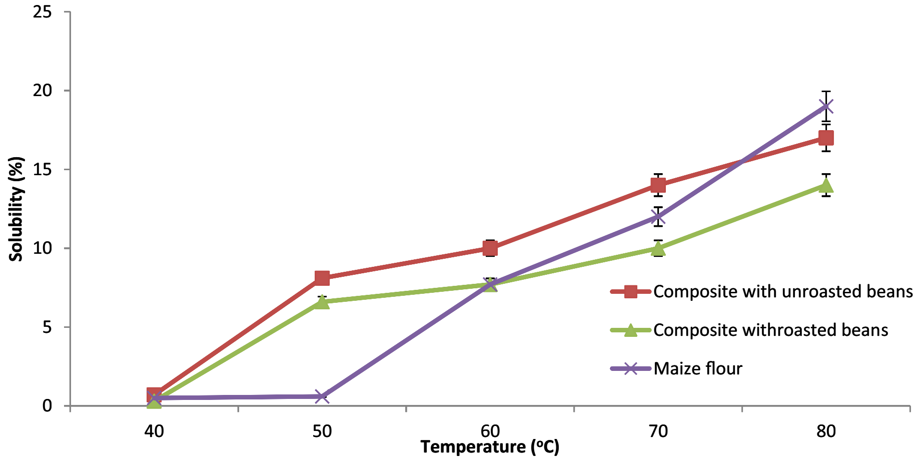

Fig. 1 Solubility of maize-based composite flour at different temperatures

composite flours formed hydrogen bonds and protein increased hydrophilicity of the flour, hence high solubility [39]. Similar findings were observed by Tumwine et al. [5] in millet based composite flours.

3.4.2 Swelling power

Results of the effect of temperature on swelling power of maize based composite four are presented in Fig. 2. The swelling power of all flours increased with increase in temperature from 2.6 to 7.8% for maize flour, 3.1 to 7.0% for maize-based composite flour with roasted beans and 3.3 to 6.4% for maize-based composite flour with unroasted beans. Between 40 and 60 °C, there was no significant difference in the swelling power of maize based composite flours but significant difference was observed between maize flour. Between 60 and 80 °C, the swelling power of flours increased gradually. The low carbohydrate content (Table 2) contributed to low starch content of maize composite flour resulting into low swelling power. Flour with low swelling power yields porridge with low viscosity. Porridge with low viscosity is important for weaning babies since their stomach volumes are small [40]. Heating flour with water results into starch gelatinisation that increases swelling power of the flour due to starch amylose leaching into hot water that results into formation of a three-dimensional network increasing the paste's viscosity [41–43]. The trend observed in this study was similarly observed by Alqah et al. [44] for sorghum flour.

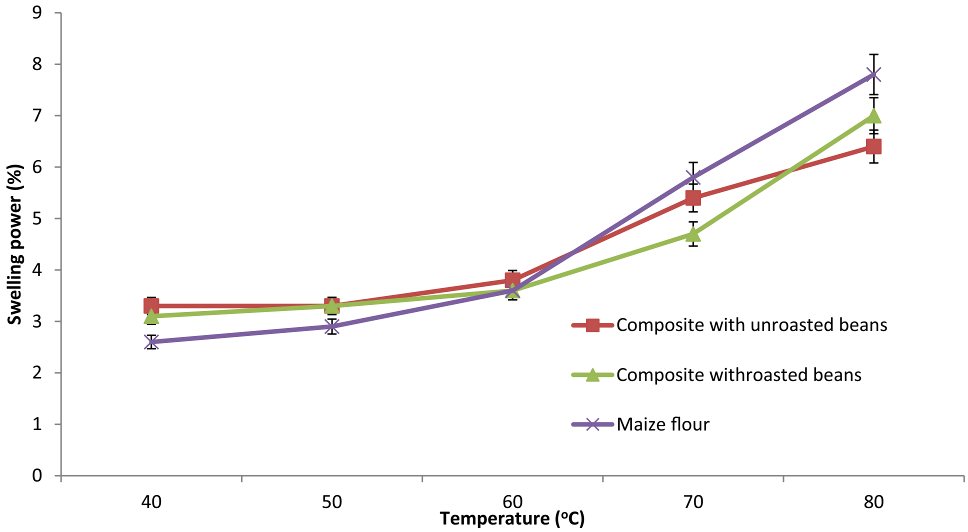

Fig. 2 Swelling power of maize-based composite flour at different temperatures

3.5 Pasting properties of maize-based composite flours

Figure 3 shows the pasting properties of maize based composite flour. Addition of beans, soy and *Rastrineobola argentea* powder flour resulted into maize based composite flour with high peak (490.33 to 839.33 cP), trough viscosity (467.00 to 803.33cP), set back (1124.00 to 1721.33cP) and final viscosities (1591.00 to 2524.67cP). Peak time (5.93 min) and pasting temperature (86.40 to 89.867 °C) of the composite flour were lower than those of maize flour (peak time; 6.93 min, pasting temperature; 93.67 °C).

The high peak and final viscosities observed in maize composite flour are attributed to high protein content. Proteins absorb water and form viscous pastes [45, 46] thus observed high viscosities. The low breakdown viscosity offers resistance to shear thinning in certain foods. This result indicates that denatured proteins in roasted beans support the structure of the matrix and slow down the shear thinning of starch in the composite flour porridges.

Peak viscosity indicates thickening behaviour and water holding capacity of starch [47]. The lower peak viscosity exhibited by maize based composite flour with unroasted beans than that with roasted beans is attributed to higher protein content that would have interfered with starch to absorb water and swell [48]. This observation suggests that composite flour with unroasted beans is a better choice for weaning children than that with roasted beans. This is because children require porridge with relatively low viscosity.

Starch paste becomes firm on cooling to 50 °C resulting into retrogradation. This decreases paste digestibility due to resistance to enzyme attack [49, 50]. The low setback value for the maize based composite flour with unroasted beans suggests a stable paste against retrogradation than composite flour with roasted beans. It also signifies easily digestible porridge for children.

The pasting temperature of maize based composite flours was significantly ($p < 0.05$) lower than that of maize flour (Fig. 3). Pasting temperature indicates a minimum temperature required for cooking porridge. The observed low pasting temperature in this study indicates lower energy required for cooking the porridge from composite flours.

3.6 Sensory evaluation of porridge from maize-based composite flours

Sensory evaluation scores of colour, aroma, taste, thickness and overall acceptability of porridge from maize-based composite flours are presented in Table 5. Porridge from maize-based composite flour with unroasted beans had higher scores for colour (7.17), taste (6.33), thickness (7.25) and overall acceptability (6.08) than that with roasted beans. On the other hand, maize-based composite flour with roasted beans had significantly higher score for aroma (5.50) than that with unroasted beans (5.33). Higher preference for colour of porridge with unroasted beans could be due to white

Fig. 3 Pasting curves for maize-based composite flours

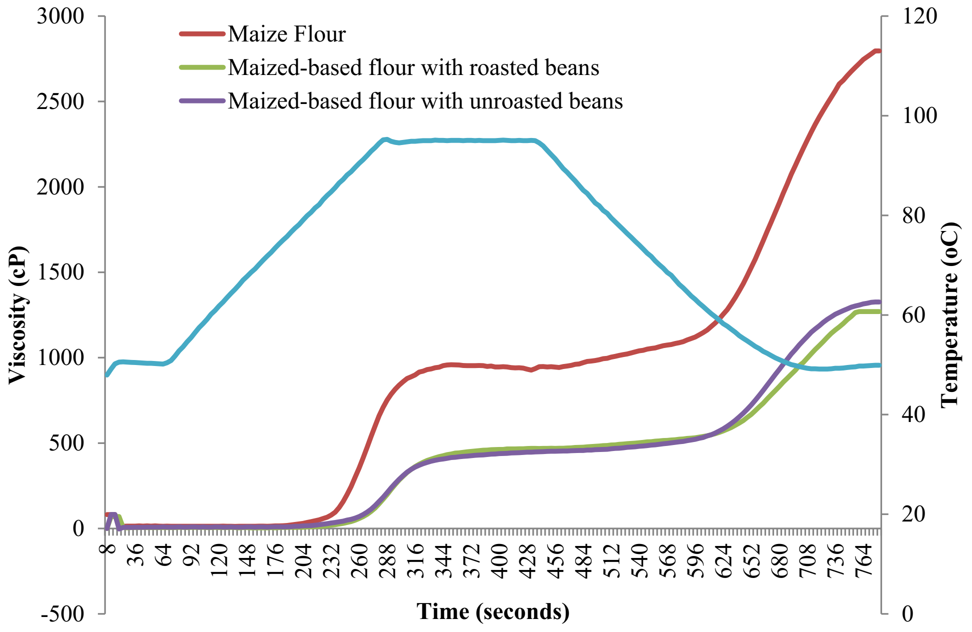

Table 5 Sensory evaluation of porridge from maize-based composite flours

Sample	Colour	Aroma	Taste	Thickness	Overall acceptability
Maize + soy + roasted beans + *Rastrineobola argentea*	6.17 ± 1.59^c	5.50 ± 1.68^b	5.25 ± 1.71^c	7.17 ± 1.11^c	5.50 ± 1.62^c
Maize + soy + unroasted beans + *Rastrineobola argentea*	7.17 ± 0.83^a	5.33 ± 1.23^c	6.33 ± 1.50^b	7.25 ± 1.06^b	6.08 ± 1.31^b
Maize	7.00 ± 1.13^b	7.33 ± 0.81^a	6.75 ± 1.42^a	7.75 ± 0.62^a	7.17 ± 1.19^a

Values in the table are means ± standard deviations of 50 untrained panellists. Means in the same column with different superscripts are significantly different

colour close to that of maize porridge unlike brown colour for porridge from roasted beans. The overall acceptability mean scores ranged from 6 (like slightly) to 7 (like moderately), none was disliked.

The higher preference for aroma from porridge with roasted beans is due to strong aroma that is developed from roasting. During roasting, there is Maillard reaction where many of the main aromatic compounds are formed. Addition of *Rastrineobola argentea*, soybean and beans resulted into porridge with lower viscosity than that of maize porridge. This is probably due to reduced levels of carbohydrates that are responsible for increased thickness of porridge. Goyat et al. [51] reported a decrease in viscosity of rice porridge with addition of chia seeds and quinoa.

4 Conclusion

The study showed that addition of *Rastrineobola argentea*, beans and soybeans improves the solubility, swelling power and nutritional properties of maize flour. Composite flour with unroasted beans resulted into porridge with the best scores for colour, taste, thickness and over all acceptability. It was also noted that addition of beans, soy and *Rastrineobola argentea* powder flour resulted into maize based composite flours with highest peak, trough, set back and final viscosities. Scaling up the production of nutrient enhanced maize based composite flour can significantly contribute to management of undernutrition in developing countries like Uganda. Even though there was a significant increase in nutrient content, functional properties and pasting properties of the developed maize-based composite flours, there is a need to explore addition of flavor enhancers or optimizing ingredient ratios to improve the sensory properties of the porridge from developed flours.

4.1 Study limitations and strengths

This study was limited to the ingredients used in the development of maize-based composite four, namely, maize, *Rastrineobola argentea*, beans and soybeans only. Secondly, the parameters of interest in this study were limited to nutritional, functional and sensory properties of the developed flours. However, the developed composite flours had other nutrients, functional and sensory properties that are significant in determining its properties. Furthermore, the nutritional properties were determined using the flour, as such future study should determine the actual nutritional properties in the porridge prepared from the developed composite fours. On the other hand, this study not only had limitations but also numerous strengths. The study tapped on the potential of locally available foods with a promising option in the development of macro and micro-enriched nutrient dense composite flour for porridge.

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Author contributions T.G and T.A.G drafted the main manuscript text. N.A, M.B, A.R and B.R reviewed the manuscript.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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