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ORIGINAL ARTICLE

Proximate composition of fermented cassava meal "mchuchume" fortified with soya bean flour and *Moringa oleifera* leaves powder

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Abstract Mchuchume is a ready to eat meal made from boiled and fermented cassava, which is mainly consumed in Western part of Tanzania. As other fermented cassava foods, it is rich in carbohydrate but deficient of other nutrients. In this study *Moringa oleifera* leaves powder (MOLP) and soya bean flour (SBF) were used to improve its nutrients. Fortification effects of MOLP and SBF were studied during separate and coetaneous inclusion. Proximate compositions of raw materials and blends were analysed. Mchuchume (control) had moisture, ash, fat, protein, fibre and carbohydrate of 68.138%, 1.090%, 0.589%, 2.068%, 5.738% and 22.367%, respectively, for SBF were 9.522%, 4.990%, 15.436%, 43.807%, 13.751% and 12.486%, respectively and for MOLP were 8.411%, 7.751%, 7.537%, 18.205%, 11.416179% and 46.681%, respectively. Mchuchume-soya had moisture (45.678% and 58.558%), ash (2.398% and 3.664%), fat (2.913% and 5.915%), protein (2.911% and 4.568%), fibre (7.373% and 9.139%) and carbohydrate (22.199% and 27.172%). Mchuchume-moringa had moisture (58.786% and 64.751%), ash (2.248% and 4.184%), fat (0.955% and 1.724%), protein (2.911% and 4.568%), fibre (6.023% and 6.626%) and carbohydrate (29.136% and 30.739%) while mchuchume-soya-moringa had moisture (45.651–58.874%), ash (2.498–4.481%), fat (1.506–4.868), protein (10.722–24.167%), fibre (6.3492–9.408%) and carbohydrate (10.203–21.239%). Mchuchume fortified with both SBF and MOLP are of the most improved nutritive values such that consumption of either of these fortified meals for a day would make an individual to meet his or her recommended dietary allowance for the nutrients analysed at a relatively lesser cost.

Keywords Fortification · Proximate composition · Mchuchume · Soya bean flour · *Moringa oleifera* leaves powder · Recommended dietary allowance

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Introduction

Cassava is the second most important source of starch (Carbohydrate) after maize, and cassava starch is traded more in international markets than any other starch source. In Africa especially the tropics, where the plant is tolerant to harsh environment such as drought and poor fertile soil it is a fourth most important source of calories and food security crop (Sulistyoa et al. 2016). As in other African countries, Tanzanian engages in cassava cultivation with production mostly concentrated in Southern and Western regions by small scale farmer and the proportion being high in Mtwara (74%) and over 85% in Kigoma region (Minot 2010). The tubers produced in Kigoma region are mainly for subsistence. Indigenous process them into several products including chips, flour and other food like ''Mchuchume'', "Kivunde", "Makopa" and "Futari". Mchuchume is a white smooth paste with slightly sour taste made by gelatinizing, fermented boiled cassava tubers. It is prepared traditionally through fermentation and then packed in banana plant leaves previously sterilized on wooden flame. It is commonly sold in markets of Kigoma Region and some areas in Mpanda, Kaliua and Biharamuro Districts in North-Western parts of Tanzania.

The problem with repeatedly consumption of cassava mchuchume stems from its poor nutritional value common with all cassava fermented products (Obatolu and Osho 1992; Ajani et al. 2016). They have adequate caloric value but low protein content (deficiently in essential amino acids), fat, fibres and micronutrients contents; therefore, they have poor nutrient quality (Tivana 2012; FAO 2008). Roasted fishes and animal meats used as accompaniments during consumption of mchuchume are highly expensive thus not accessible to low income individuals. As a result consuming mchuchume alone risk consumers to protein-energy malnutrition which is a public health problem in most sub Sahara Africa, including Tanzania. The prevalence of undernourishment in these areas is an overturn to persistent dependence on starchy foods; the major crops mostly roots and tubers, and cereals due to increasing high cost of traditional sources of animals and fishes proteins (Olapade et al. 2014; TFNC 2014). Efforts to add nutrients such as protein, minerals and vitamins into cassava foods are on the way (WHO/FAO 2006; Montagnac et al. 2009). Legumes and plant leaves are some of the low-priced sources of nutrients rich foods (Fashakin et al. (1986); Neumann et al. 2018). Studies on the enrichment of local starchy foods with legumes seeds and plant leaves such as soybean, groundnut, *Moringa oleifera* leaves and cassava plant leaves have been carried out in different locations (Abraham et al. 2013; Bankole et al. 2013; Ajani et al. 2016). Both soya beans and *M. oleifera* leaves are nutritious stuff enough for utilization as vehicle materials to substitute the carbohydrate content of tubers (Mensah et al. 2017).

Soya bean is one of the known vegetable with exceptional nutritional profile. It contains high level of good quality protein like those found in milk and egg. Its fat is 60% polyunsaturated and the 8% is omega 3. It is also a reservoir of micronutrients including vitamin E, group B vitamins and minerals such as iron, manganese, phosphorus, potassium, zinc, copper and calcium (Otegbayo et al. 2013). Soya bean has numerous nutritional values not well known by consumers of soya bean products (Balogun et al. 2012). On the other hand *M. oleifera* is also a nutritious plant with potential uses for its flower, pods, roots and the leaves of which are consumed as vegetable soup, dried powder, or blended juice (Moyo et al. 2011). The leaves are good sources of protein, vitamins, phytochemicals and minerals indicated by high ash and crude fibre contents. Moringa plant is non-commodity crop domestically available at cheaper cost in most of sub Sahara Africa including Tanzania. However, it is one of the neglected and underutilized crops in the regions (Padulosi et al. 2013).

Combining two or more food stuffs had been viewed important to improve nutritive quality of our local food since no single food that contains all of the require nutrients (Gisulga and Galvez 2017). This could enable fighting various forms of malnutrition in easier and cheaper way for the developing countries. Because of their diverse compositions, functional food systems comprising soya beans and *M. oleifera* leaves pose technical challenges for production of products with high nutritional value that could meet recommended dietary allowances (Rweyemamu 2006). Therefore this study was carried out to investigate the synergistic effect of these foods as nutrient enrichment materials and compare their individual contribution on proximate composition of blended mchuchume.

Materials and methods

Sample collection

Samples of cassava tubers (KBH 2006/482-Kizimbani) aged 8–10 months were harvested from Mikocheni Agricultural Research Institute at Chambezi centre in Coast region, Tanzania. Harvested samples were transported to University of Dar es Salaam for further studies. Small branches of *M. oleifera* were harvested from Yombo garden at University of Dar es salaam while Soya bean (*Glycine max*) was purchased from the whole sale grain vendor at Manzese market, in Dar es Salaam, Tanzania.

Preparation of raw materials

Preparation of cassava meal "Mchuchume"

Cassava tubers were washed using potable water to remove soil particles and then peeled. The samples were divided into smaller pieces of about 2 × 2 cm using knife followed by defibring. They were poured in the saucepan containing tap water and then boiled on hot plate at 50 °C for 45 min. Boiled tubers were fermented, drained and pounded to produce the cassava meal "Mchuchume".

Preparation of Moringa oleifera leaves powder

Preparation involved detaching leaflets from branches, sorting and washing. During washing leaflets were washed in running water, 1% saline solution (NaCl) at 1:5 leaves to water ratio, 70% ethanol at 1:5 leaves to water ratio and rinsed with deionized water. These steps played an important role of removing dust, pathogens as well as microbes present on a leaf surface. Washed leaves were blanched at 80 °C for 2 min to inactivate metabolic activities in the leaves, drained on the sterile wire mesh and then shed dried in sterile green tent drier at 29–32 °C and relative humidity of 75–80% for 5–6 days. The leaves were blended and then sieved into powder that was packed in airtight and opaque packages (plastic bags LDPE) and stored at + 4 °C.

Preparation of soya bean flour

The preparation of soya beans involved sorting, blanching, de-hulling, dry extrusion and milling. Blanching was done for 3 min into a heating medium of greater than 1:10 soya beans to water ratio (water boiling at 99 ± 1 °C); followed by sun drying at 29–32 °C and relative humidity of 75–80%. The final moisture content of the soya was 10–11%. Milling was carried out using a hammer mill with 300 µm screen to produce fine soya bean flour.

Formulation of enriched cassava meal "mchuchume" blends

The raw materials used for preparation of fortified mchuchume were fermented cassava meal mchuchume (FCM), extruded soya bean (*Glycin max*) flour (SBF) and *M. oleifera* leaves powder (MOLP). Samples used during fortification were varied at; (50–80)%, (15–35)% and (5–15)% for raw mchuchume, soya bean and *M. oleifera,* respectively. The ranges were selected in order to produce a food that could meet Recommended Dietary Allowance of the studied nutrients among various groups of consumers. The design expert version 10 software was used to develop the ratios. The corresponding ratios of raw materials were mixed thoroughly using blender (PO.I.II SG BGN 100, China).

Production of two components blends The proportions of SBF and MOLP used to produce cassava mchuchume—soya bean flour (CS) and cassava mchuchume—*M. oleifera* leaves powder (CM) blends were prepared using the formulations designated below.

FCM = 100% mchuchume (control)
CS1 = 65% FCM : 35% SBF
CS2 = 85% FCM : 15% SBF
CM1 = 85% FCM : 15% MOLP
CM2 = 95% FCM : 05% MOLP

The total formulation of the blends was 300 g

Production of three components blends Eleven different types of blends were prepared and fresh mchuchume was used as control. The three components mixture; mchuchume-soya-moringa blends (CSM) were prepared using the formulations designated below.

CSM1 = 80% FCM: 15% SBF : 05% MOLP
CSM2 = 74% FCM : 16% SBF : 10% MOLP
CSM3 = 74% FCM: 21% SBF : 05% MOLP
CSM4 = 70% FCM : 15% SBF : 15% MOLP
CSM5 = 68% FCM : 27% SBF : 05% MOLP
CSM6 = 65% FCM : 24% SBF : 11% MOLP
CSM7 = 65% FCM: 20% SBF : 15% MOLP
CSM8 = 62% FCM : 33% SBF : 05% MOLP
CSM9 = 56% FCM : 35% SBF : 09% MOLP
CSM10 = 56% FCM: 29% SBF : 15% MOLP
CSM11 = 50% FCM : 35% SBF : 05% MOLP

The total formulation of the blends was 250 g

Proximate composition analysis

Determination of moisture content

A mass of about 2 g for each sample was weighed in pre-conditioned petri plate. Samples were dried to constant mass in hot air oven at 105 °C overnight (AOAC 2005). The loss in weight was used to calculate moisture content using Eq. (1).

$$\text{Moisture content } (\%) = \frac{W_2 - W_0}{W_1 - W_0} \times 100\% \tag{1}$$

where W_0 = Weight of plate (g); W_1 = Weight of plate + sample before drying (g); W_2 = Weight of plate + sample after drying (g)

Determination of ash

About 2 g of each sample was weighed into pre-conditioned porcelain crucible and incinerated in muffle furnace preheated to 550 °C for 5 h (AOAC 2005). Crucibles were cooled in desiccators to room temperature and then re-weighed. Ash contents of samples were calculated from Eq. (2).

$$\text{Ash content } (\%) = \frac{M_2 - M_0}{M_1 - M_0} \times 100\% \tag{2}$$

where M_o = Weight of crucible (g); M_1 = Weight of sample and crucible before incineration (g); M_2 = Weight of ash and crucible after incineration (g)

Determination of crude fat

Pre-conditioned aluminium cups containing 30 mL of n-hexane were placed under the adapters holding thimbles previously loaded with 2 g of a samples on the soxtec system (Foss soxtec™ 2043, Sweden). Fat in the sample was extracted by submerging the thimbles in boiling *n*-hexane for 20 min. Fats lagged in the samples were rinsed out by reflux with boiling *n*-hexane for 45 min. Excess *n*-hexane was recovered by evaporation from the cups into the condenser unit of soxtec for 10 min thereafter extracted fats in the cups were dried in the hot air oven for 30 min (Foss analytical 2003b). Amount of extracted fats in dry matter basis were then calculated using Eq. (3).

$$\text{Fat }(\%) = \frac{(F_2 - F_1)}{F} \times 100\% \tag{3}$$

Where F_2 = Weight of cup and dried fat; F_1 = Weight of empty cup; F = Weight of sample

Determination of crude fibre

About 2 g of each sample was weighed into fibre crucibles that were then fixed underneath fibertec glassier columns (Foss Fibertec™ 1020, Sweden). 100 mL of hot H_2SO_4 (1.25%) was added in the glassier columns to hydrolyze organic substances (e.g. protein, carbohydrate) with occasion auto-heating for 30 min. Resulted residues were washed with hot deionized water followed by addition of hot NaOH (1.25%) to effect saponification of fat in the sample again for 30 min. Sample residues were further washed with hot water thereafter dried for 2 h in hot air oven at 130 °C. Crucibles with dried sample residue were ignited in the muffle furnace at 550 °C for 5 h and weighed again after cooling during incineration (Foss Analytical 2006). Crude fibre contents of samples (dry matter basis) were then calculated using Eq. (4).

$$\text{Crude Fibre }(\%) = \frac{(B_2 - B_1)}{B_0} \times 100 \tag{4}$$

Bo = Sample weight; B1 = Weight of crucible + residue after incineration; B2 = Weight of crucible + residue before incineration

Determination of crude protein

A weight 2 g of each sample were put into labeled kjeltic tubes followed by addition of kjeltic catalyst [3 selenium oxide (2 g) tablets] and 20 mL of concentrated sulphuric acid (98%). The tubes and the contents were plunked in the digestion unit (Foss tecator™ Digester, Sweden) and digested completely (until white fumes and blackish mass absent) for 2 h at 400 °C. The digests were left to cool at room temperature and distilled using Auto distillation unit (Foss Kjeltic™ 8200, Sweden) that was earlier rinsed and calibrated with the following set up.

- Dilution volume was 80 mL (deionized water)
- Receiver solution was 30 mL (Boric acid 4%)
- Sodium hydroxide was 50 mL (40% solution NaOH)
- Mixed indicator (3 mL)
- Distillation time was 5 min

The distillates collected in the flasks were titrated with 0.0956 M hydrochloric acid using digital burette (Foss analytical 2003a). Amount of protein in the sample (dry basis) was calculated according to Eq. (5).

$$\%\text{ Protein} = \frac{(T - B) \times M \times 14.007 \times 100 \times 6.25}{W} \tag{5}$$

where, T = Volume of the standard hydrochloric acid used in the sample titration; B = Volume of the standard hydrochloric acid used in the blank titration; M = Molarity of the acid in four decimal places; W = Mass of the sample used in the determination.

Determination of carbohydrate

The carbohydrate content was determined by differences (AOAC 2005). Sum of all measured proximate component was subtracted from hundred (100%) as shown in Eq. (6).

$$\begin{aligned}&\%\text{ Carbohydrate}\\&= \%100 - (\%\text{ moisture} + \text{ash} + \text{fat} + \text{protein} + \text{fibre})\end{aligned} \tag{6}$$

Statistical analysis

Statistical Package for Social Statistics (IBM SPSS statistics 21) was used for analysis. All data were reported as means + standard deviation of triplicate determinations. One way ANOVA was used to compare means of collected data from all samples for each measured parameter. To verify the variance homogeneity and identification of significant differences ($p \leq 0.05$) the Tukey's HSD and Duncan Multiple Range tests were applied.

Results and discussions

Characterization of the raw materials

The individual samples; fermented cassava meal "mchuchume" (FCM), soya bean flour (SBF) and *M. oleifera* leaves powder (MOLP) showed significant difference ($p < 0.05$) based on ash, fat, protein, fiber and carbohydrate contents. The nutritional composition of SBF and MOLP analyzed were important in estimating quantities used during fortification of mchuchume so that consumption of reasonable amount of developed product could result into feeding a human body with nutrients that meet Recommended Dietary Allowance of various age groups.

FCM had the lowest amounts of fat (0.589%), crude protein (2.068%) and crude fibre (5.738%) compared to that of MOLP (7.537, 18.205 and 11.416, respectively) and SBF (15.436%, 43.807% and 13.751%, respectively). On the other hand MOLP had the highest ash (7.75%) compared to that of SBF (4.99%) and FCM (1.09%). This indicated that MOLP is a better source of mineral than FCM and SBF. Analysis also showed that the carbohydrate value of MOLP was higher (46.681%) than that of FCM (22.908%) and SBF (12.48) (Fig. 1).

The results for ash, fat, protein and fibre content of FCM (Table 1 and Fig. 1) are similar to that reported in lafun by Balogun et al. (2012) worked on soybean-fortified lafun and Bankole et al. (2013) on cassava lafun fortified with soya bean. Likewise, SBF had ash, fat, protein, fibre, carbohydrate and moisture contents which agreed with that reported in previous studies (Siulapwa and Mwambungu 2014; Gupta et al. 2013). In addition, all the proximate values except protein content of MOLP agreed with that reported by Moyo et al. (2011). The recorded protein content of MOLP was lower than that reported by previous study. This might be due to preparation method used in this study, the blanching method conducted at 80 °C which might destroyed/denatured some of the nutrients. Difference in geographical location and leaves maturity might also be the factors for the variations.

Proximate composition of two components fortified "mchuchume"

There was a significant increased ($p < 0.05$) of proximate contents in the control samples (CMF 100%) on the course of blending with respect to proportions of fortifying material used except moisture of all samples and carbohydrate of CS2 that decreased significantly ($p < 0.05$) (Table 1).

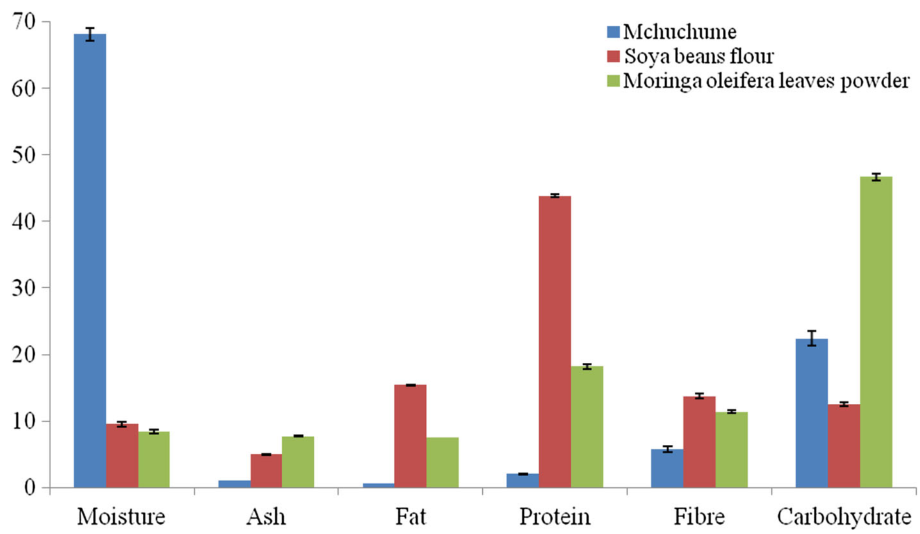

Fig. 1 Proximate compositions of raw materials

Table 1 Proximate composition of two components fortified "mchuchume"

Sample	Ratio	Proximate compositions					
		Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fibre (%)	Carbohydrate (%)
FCM	100	68.138 ± 0.938	1.090 ± 0.017	0.589 ± 0.007[a]	2.068 ± 0.0516[a]	5.738 ± 0.471[a]	22.367 ± 1.102[a]
SBF	100	9.522 ± 0.36	4.990 ± 0.026	15.436 ± 0.067	43.807 ± 0.209	13.751 ± 0.391	12.486 ± 0.324
MOL	100	8.411 ± 0.23	7.751 ± 0.109	7.537 ± 0.062	18.205 ± 0.326	11.416 ± 0.179	46.681 ± 0.523
CS1	65:35	45.678 ± 0.381	3.664 ± 0.250[a]	5.915 ± 0.278	17.570 ± 1.588	9.139 ± 0.498	27.172 ± 1.434[b]
CS2	85:15	58.558 ± 0.407	2.398 ± 0.239[b]	2.913 ± 0.142	13.933 ± 0.226	7.373 ± 0.146[b]	22.199 ± 0.730[a]
CM1	85:15	58.786 ± 0.253	4.184 ± 0.307[a]	1.724 ± 0.182	4.5680 ± 0.373	6.626 ± 0.140[abc]	30.739 ± 0.689[bc]
CM2	95:5	64.751 ± 0.071	2.248 ± 0.131[b]	0.955 ± 0.050[a]	2.911 ± 0.020[a]	6.023 ± 0.045[ac]	29.136 ± 0.126[c]

n = 3, Means followed by the same superscripts within a column do not differ significantly

*All values are presented in per 100 g dry matter of edible food, mean ± standard deviation

$p > 0.05$

In CS1 which was made of CFM and SBF in the ratio 65:35, the protein, ash, fat, fibre and carbohydrate increased by 749%, 236%, 904%, 59% and 21%, respectively relative to the control. The CS2, CFM:SBF (85:5) was observed to contain protein, ash, fat, and fibre increased by 574%, 120%, 395% and 28%, respectively while carbohydrate and moisture decreased by 0.75% and 14%, respectively relative to the control (Table 1).

When MOLP was used as fortifying material, CM1 made of FCM and MOLP in the ratio of 85:5 the protein, ash, fat, fibre and carbohydrate increased by 121%, 284%, 193%, 15% and 37%, respectively relative to the control. The CM2, FCM:MOLP with mixing ratio of 95:5 had protein, ash, fat, fibre and carbohydrate increased by 41%, 106%, 62%, 5% and 30%, respectively relative to the control (Table 1). The results depict that supplementation of mchuchume with soya bean flour had a greater impact on protein, fat and fibre contents than the effect observed in the use of moringa leaves powder which had the highest effect on ash and carbohydrate content. In view of proportions of individual fortifying material used, the magnitude was a determinant of the nutritional effect they posed in the blends.

The percentage improve in the nutritional quality of mchuchume fortified with soya beans flour that were observed in this study for 35% substitution (749%, 236%, 904%, 59% and 21% for protein, ash, fat fibre, respectively) strongly deviate from that reported by Adeniyi et al. (2017) of which 108.0%, 18.7%, 90.2%, and 117.5% were the percentage increases in protein, ash, fat and fibre, respectively in the sample contain 40% soya flour. Similarly, Bankole et al. (2013) reported that fortifying cassava flour (lafun) with soybean at 10%, 20%, 30% and 40% significantly improved both nutritional and functional properties but surprisingly the protein, ash, fat and fibre content were 12.54%, 2.46%, 2.62%and 2.12% in the sample with highest substitution of 40% soybean. These values are quite lower compared to that obtained in this study. This might be due to difference in preparation methods of soya beans (such as high temperature short time (HT-ST) extrusion) used in this study. On the same vein, Kouevi (2013) reported that substitution of cassava tuber with 5% and 15% of *M. oleifera* leaves powder for production of weaning food in West Africa gave maximum protein content of 9.2% and 11.6%, respectively. These values were higher compared to that obtained in this study (2.911% and 4.568%). As reported in the previous section, some of the nutrients might be destroyed during blanching in the preparation process of *M. oleifera*. In addition, geographical location and leaves maturity might also be the factors for these variations. It was also revealed that the proximate composition of the blends increased significantly with increase in the supplementation levels of soya bean flour and *M. oleifera* leaves powder, respectively. This confirmed to what earlier reported by Fashakin et al. (1986). On these bases, blend with highest protein content was obtained at 35% soya bean flour substitution and could completely met Recommended Dietary Allowance for children aged 4–8 years. Other mixing ratios had levels of protein out of Recommended Dietary Allowances.

Proximate composition of three components fortified "mchuchume"

Proximate compositions of the blends increased significantly ($p < 0.05$) relative to the control except the moisture and carbohydrate content that decreased significantly ($p < 0.05$).

The control sample had ash (1.090 ± 0.017%), fat (0.589 ± 0.008%), protein (2.068 ± 0.0516%) and fibre (5.738 ± 0.471%) while that of CSM blends ranged from 2.498 ± 0.060% to 4.481 ± 0.129%, 1.506 ± 0.213% to 4.868 ± 0.039%, 10.722 ± 0.513% to 24.167 ± 0.158% and 6.3492 ± 0.031% to 9.408 ± 0.192%, respectively. The ash, fat, protein and fibre contents in CSM blends were higher than that of the control due to addition of both SBF and MOLP. Coetaneous inclusion of SB and MOLP brought a synergistic elevation of these nutrients in the CSM blends. The impact of collaborative fortification of SBF and MOLP is also supported by spread in percentage increase in ash, fat protein and fibre of CSM blends that were 129% to 311%, 156% to 495%, 418% to 1069% and 11% to 44% respectively against the value observed in the CS blends (120% to 236%, 395% to 904%, 574% to 749% and 28% to 59%, respectively and CM (106% to 284%, 62% to 193%, 41% to 121% and 5% to 15% respectively). Mixing ratios in CSM blends had the influence on proximate composition due to improved nutrient contents observed (Fig. 2).

The moisture content of control sample was 68.138 ± 0. 330% while that of CSM blends ranged from 45.651 ± 0.131% to 58.874 ± 0.147%. The highest moisture content of the control was expected. The presence of dry SBF and MOLP rich in protein and carbohydrates which are hydrophilic substances might have caused absorption of water from FCM and subsequently resulted into moisture deduction. The water imbibed by SBF and MOLP may not be releases as free water that can be determined during moisture content determination. There were low carbohydrate contents (10.203 ± 1.368% to 21.239 ± 0.822%) in CSM blends relative to that of a control (22.367%). The reduction in carbohydrate content of the blends was possibly because of its substitution with in fluxed nutrients.

According to Fashakin et al. (1986) it was expected that formulations for CSM1 and CSM11 could have yielded

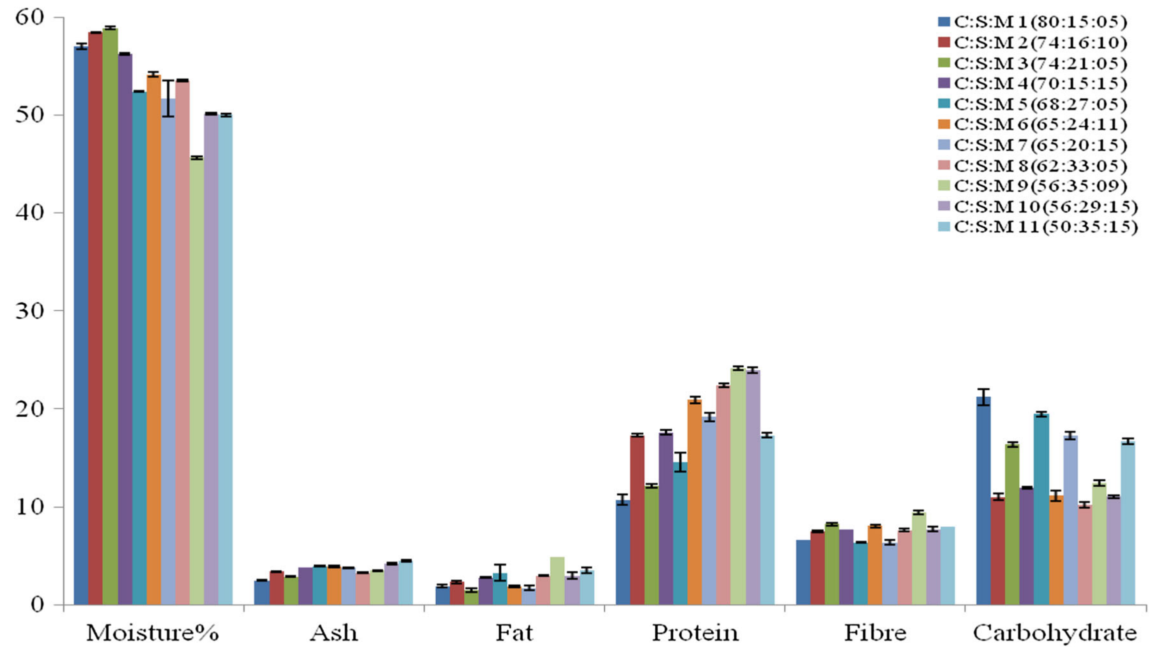

Fig. 2 Proximate composition of three component fortified mchuchume

Table 2 Recommended dietary allowance for protein (g/day) needed by various groups (www.nap.edu)

Age (years)	4–8	9–13	14–18	19–30	31–50	51–70	71+	Pregnancy	Lactation
Male	14.5	19.7	52	56	56	56	56	–	–
Female	14.5	19.7	46	46	46	46	46	71	71

lowest and highest levels of proximate components, respectively however, this was not a case. The deviations encountered in the observation might have attributed by interaction in functional food systems of mchuchume, soya bean flour and *M. oleifera* leaves powder existed during processing (Rweyemamu 2006). Along dispersion of blends produced, only CSM1 had protein content (10.722 g) with serving size of 100 g that do not meet RDA for any group listed in Table 2. Other blends with the same serving size were in satisfactory position at least to meet the lowest RDA for children aged 4–8 years.

Nutritional implication

The cassava meal "mchuchume" fortified with both soya bean flour and *M. oleifera* leaves powder is nutritionally relevant based on how it reflects on the Recommended Dietary Allowance. Table 2 presents RDA for protein that could be met when mchuchume-soya-moringa produced in this study is consumed by different categories of age groups.

Largest amount of protein (24% or 24 g/100 g) was found in CSM9 blend, and thus when consumed in a day of 100 g as serving size, children aged 4–8 years and 14–18 years will have a surplus of 9.5 g and 4 g protein, respectively. Boys (14–18 years) will meet RDA by 46.15%, girls (14–18 years) by 52.17%, adult male (19–71 + years) by 42.86%, adult female (19–71 +) by 52.17% and woman (lactating and pregnant) by 33% (Table 2).

Mchuchume is a popular food consumed as breakfast, lunch and dinner not only by indigenous but also refugees from Republic of Congo and Burundi who flee to camps in Kigoma region, Tanzania due to political tensions in their countries. According to nutrition surveys done by UN (2013), the rate of severe acute malnutrition (SAM), global acute malnutrition (GAM) and the prevalence of stunting among the refugees reserved in the camps of Kigoma Region were found to be 2.6%, 0.95 and 46%, respectively. Therefore, utilization of mchuchume-soya-moringa blends by this group could be the easier and cheaper approach to intervene the incidences of malnutrition problems and other disease related to eating habits. Consumers of mchuchume-soya-moringa prepared in this study will be able to meet the RDA for protein and possibly other nutrients.

Conclusion

The results of this study accept fortification of mchuchume at 56:35:09 levels of fortification with both soya bean flour and *Moringa oleifera* leaves powder so as to yield nutrient densest food. Producing mixed food stuffs from nutritious plants as soya bean seeds and moringa leaves is very worth strategy and thus consumer could meet RDA for protein at affordable cost relative to mchuchume fortified using individual plant.

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