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Title: Enrichment of fermented cassava meal "mchuchume" with micronutrient ingredients from Soya bean flour and *Moringa oleifera* leaves powder

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Abstract

Background

"Mchuchume" is a ready to eat fermented cassava food (FCM) used for breakfast, lunch and/or snack purposes. Its diverse consumption modes attract more researches including its fortification with inexpensive food materials rich in beneficial nutritional qualities. This study aimed at investigating effect of soya bean flour (SBF) and *Moringa oleifera* leaves powder (MOLP) on the micronutrient composition of "mchuchume".

Results

Enrichment significantly increased iron (0.001 g kg^{-1} in control to 0.03 g kg^{-1} in cassava-soya, 0.06 g kg^{-1} in cassava-moringa and 0.09 g kg^{-1} in cassava-soya-moringa) and potassium (1.01 g kg^{-1} in control to 5.14 g kg^{-1} in cassava-soya, 3.45 g kg^{-1} in cassava-moringa and 7.43 g kg^{-1} in cassava-soya-moringa). There was significant decrease of sodium content (0.10 g kg^{-1} in the control to 0.09 g kg^{-1} in cassava-soya) and significant increase of sodium content (0.37 g k g^{-1} in cassava-moringa and 0.36 g kg^{-1} in cassava-soya-moringa). β-carotene was below the limit detection of instrument (< 0.2 x 10^{-6} g/mL) in the control and cassava-soya blends but detected in cassava-moringa (0.01 g kg^{-1} to 0.02 g kg^{-1}) and cassava-soya-moringa blends (0.01 g kg^{-1} to 0.02 g kg^{-1}).

Conclusion

Mchuchume fortified with both MOLP and SBF has micronutrients at recommended dietary allowances. The food is recommended for use in management of iron and vitamin A deficiencies which are endemic not only to inhabitants and refugees of Kigoma region in Tanzania but also to people in most of African countries and other cassava consuming developing nations.

Key words: Micronutrient, cassava meal "mchuchume", soya bean flour, *Moringa oleifera* leaves powder, recommended dietary allowance.

1. Introduction

Cassava (*Manihot esculenta* Crantz) utilization for human food is either indirect or direct. It can be used as raw material to make other food products or consumed alone after being boiled in water, fried in oil, roasted in an open fire or after fermentation. Cassava offers nearly 45% of all calories consumed in Africa and it generates income for the largest numbering households.[1,2] It has been processed into many human food products and there are still emerging new products. Cassava has many alternatives uses that numerous identifies it as food security crop.

In light of its potential as food security crop and staple food of many people, cassava could be used in fighting malnutrition; however, its main limit is the relatively poor amounts of nutrients of public health significance. It contains only 30 to - 35 g kg^{-1} crude protein, 1-35 x 10^{-5} g kg^{-1} β-carotene and 0.003 – 0.14 g kg^{-1} iron[2,3]. Additionally, its traditional processing methods to produce local food consumed in large quantity by various societies encompass several steps including peeling, soaking, grinding, steeping in water or left in air to allow fermentation, drying, milling, roasting, steaming, pounding and mixing in cold or hot water. Specifically, combination of these steps leads to a myriad destruction and/or loss of nutrients. Subsequently, repeatedly consumption of cassava-based products has been implicated in paving malnutrition primarily protein, iron and vitamin A deficiencies.[4] Micronutrients deficiencies partly develop when people's diets lack food diversification as in overdependence on staple food alone like in the case of cereals or root based foods including cassava.[5]

A report by WHO[6] indicated that malnutrition affects close to 800 million people in the world. In Africa, 46% of the total population is anaemic, 43% have insufficient iodine intake and 46% of pre-school children are vitamin A deficient.[5] Reports on these wide and growing nutritional problems have readily been mentioned even in Tanzania.[7] A recent report indicated that there was a high level of under nutrition among children and woman and that the diet was too low in micronutrients and too high in carbohydrates[7], however, these vulnerable groups do not excellently engage into iodine, vitamin A and iron-folic acid supplementation programmes [5,7]. According to the Tanzania Food and Nutrition Centre[7], during a nutrition status survey in Tanzania, 34.7% of children aged 0-59 months were identified with stunting or chronic malnutrition and about 28.0% of the children did not receive vitamin A supplement. Women (15 – 49 years) surveyed 5.5% were underweight while 20% were found overweight and 30.9% of women with children less than five years of age, didn't take iron-folic acid supplementation during pregnancy for past birth. In addition, Kigoma region was among the six (6) regions in Tanzania identified in demand of micro-nutrition intervention prioritization. The report by Allen *et* al[5] had suggested that constrains incurred by nutrient supplementation programme in a national policy could partly be resolved at community level through food fortification. Fortifying food to improve micro-nutrients of public health concern; iron, iodine and β-carotene has gained momentum over the years.[5,8]

A wide range of studies have shown potential value of improving micronutrient nutritional quality of starchy staples such as cassava using other plant food-stuffs.[1,8-11] However; a reliable approach of food to food fortification for convenient addressing malnutrition problems in developing countries should utilize vehicles selected among traditional condiments.[8] Soya beans and *Moringa oleifera* are commonly available throughout the East Africa. They have beneficial nutritional qualities and they are inexpensive sources of both macro and micronutrients.[12] For many years, soybean has been processed into a wide variety of food products that are consumed in large quantities in Africa, the United States of America and Asian countries.[13] *Moringa oleifera* is considered as plant of great nutritional importance due to its dense nutrient content and presence of other essential bioactive compounds.[14] Nevertheless, the nutritional value of soya bean and *Moringa oleifera* as sources of minerals are limited by presence of antinutritional factors including some of tannins, polyphenols, oxalate and phytates.[13,15] These factors lower digestibility, bioavailability and bioaccessibility of micronutrient such as iron, zinc and phosphorous in soya and *Moringa oleifera* products. But; studies had shown that improved processing through application of heat and incorporating organic acids such as high content of ascorbic acid from *Moringa oleifera* in soya products lower the contents of the anti-nutritional factors.[13,15]

On top of that, the other greatest challenge of food processing in developing countries is the transformation of traditional or indigenous methods into modern operations that could explain innovations capable of retaining nutrients in a food product.[16] For instance, Kigoma region identified for micro-nutrition intervention prioritization by TFNC[7] has underutilization of fermented cassava meal “mchuchume” as micronutrient carrier to the society. “Mchuchume” is a famous cassava food in Western parts of Tanzania, Burundi, Rwanda and Democratic Republic of Congo. It is ready to eat white paste with a slightly sour taste normally consumed with roasted meat and fish.[11] This food has a diverse consumption mode as being snack, breakfast and lunch. It is also a farmers’ and travelers’ reserve food due to its great ability to resist spoilage.

Efforts have been made to improve processing of this food by encouraging diversification of its components to exploit optimized nutritional quality and other important attributes. Previous study had reported the enhancement of mchuchume’s macronutrients using Soya bean flour and *Moringa oleifera* leaves powder.[11] This study, however, seeks to investigate effect of these fortificants on micronutrient composition of “mchuchume”. The study is of key importance as essential prelude to further studies on the food’s storage and preservation.

2. Materials and Methods

2.1 Source of raw materials

Cassava roots (KBH 2006/482-Kizimbani aged 8-10 months) were sourced from Mikocheni Agricultural Research Institute at Chambezi centre in Coast region, Tanzania. Small branches of *Moringa oleifera* were harvested from Yombo garden at University of Dar es salaam while Soya bean (*Glycine max*) was purchased from the whole sale grain vendors at Manzese market in Dar es Salaam region, Tanzania.

2.2 Preparation of Raw Materials

2.2.1. Preparation of fermented Cassava meal "Mchuchume" (FCM)

Improved method for preparation of mchuchume was used. It involved washing cassava roots, peeling, slicing and then removing woody vascular bundles using knife. Slices were poured in the saucepan containing portable tap water and then boiled until cooked for 45 minutes at 50 ˚C. Boiled roots were fermented in closed system containing Lactobacillus *delbrueckii* (WLP677, INDIA) starter culture, dried in the oven at 40 ˚C (WTB binder Model 78532, Germany) and blended using stainless steel blender (PO.I.II SG BGN 100, China) to produce the cassava meal "*Mchuchume*".[17]

2.2.2. Preparation of Moringa oleifera leaves powder (MOLP)

Leaflets were detached from branches, sorted and 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. Washed leaves were blanched at 80 ^{o}C for 2 minutes to inactivate metabolic activities in the leaves and decrease risks of anti nutritional factors. They were drained on the sterile wire mesh and then dried in sterile green tent at room temperature (30 ^{o}C) and relative humidity of 75% for 6 days. The dried leaves were blended to fines using stainless steel blender (PO.I.II SG BGN 100, China) and sieved using a net sized 50 μm. The powder was then packed in airtight and opaque plastic bags (LDPE) and stored at chilling temperature (-4 ^{o}C) for further analyses.

2.2.3. Preparation of soya bean flour (SBF)

Soya beans were sorted to remove grasses and stone pieces, blanched (water boiling at 99 ± 1°C) for 3 min, de-hulled and dry extruded using cone discharge expander (Model-Exp 250-10"; Group Tecnal, Rodovia Raposo Tavares, Ourinhos, Brazil) at an average pressure of about 4 MPa, a maximum temperature of about 108°C, and a retention time of 120 s (high temperature short time, HTST technology). Extruded soybeans were milled using the hammer mill of 300 μm screen (Retsch GmbH 5657 WEST GERMAN) to produce soya bean flour.

2.1 Formulation of enriched cassava meal "mchuchume" blends

Samples used during fortification were varied from 50 to 80%, 15 to 35% and 5 to 15% for FCM, SBF and MOLP, respectively. These ranges of components were calculated by material balance based on the iron and β-carotene content of the raw materials in order to obtain blends that could meet Recommended Dietary Allowance of the studied nutrients for various groups of consumers. Two component blends (Table 1) were prepared in order to evaluate nutritional influence of each fortificant in the three component blends. Design expert version 10 software manipulated developed ranges of fortificants into distinct eleven mixing ratios that were used to formulate three component cassava-soya-moringa (CSM) blends (Table 2).

Table 1:

Table 2:

Unfortified mchuchume was used as control. Quantities of fortificants FCM, SBF and MOLP as manipulated by design expert were thoroughly mixed using a stainless steel blender (PO.I.II SG BGN 100, China) at a total mass of 0.3 kg and 0.25 kg for two and three components blends, respectively.

2.4 Analyses of Micronutrients

β-carotene analysis was carried out at Eastern African Regional Hub Food laboratory of International Institute of Tropical Agriculture (IITA), Tanzania and minerals at Chemical and Mining processing laboratory of University of Dar es salaam, Tanzania.

2.4.1 **Determination of pro-vitamin A (β-carotene)**

2.4.1.1. Preparation of standard curve

Standard calibration curve for β-carotene was obtained by plotting the trans-β-carotene peak area against the trans-β-carotene concentration at 5 levels. The response of trans-β-carotene over a concentration that ranged from 3.214–51.42 mg/L was linear (Y= 129232X – 635176) with a regression coefficient (R^2) of 0.9873.

2.4.1.2. Test sample analysis

β-carotene from samples was extracted, concentrated, partitioned, saponified and dried relevantly based on HPLC method by Rodriguez-Amaya and Kimura. [18] Sample aspiration in HPLC was in accordance to HPLC manual.

2.4.2. Determination of Mineral contents

The Atomic Absorption Spectroscopy method was used to determine mineral contents in the test samples following the methods described by Paul *et al*.[19] It involved sample drying, digestion, filtration, dilution and aspiration into the Atomic Absorption Spectroscope (AAS).

2.5 Statistical Analysis

Samples were analysed in triplicate (n =3) and the data reported as mean ± standard deviation (SD). Analysis for differences used Statistical Package for Social Statistics version 21(IBM SPSS Inc., Armonk, NY, USA). Means testing were by one-way analysis of variance. When the main effect was significant ($p < 0.05$) the use of Least Significant Difference for raw materials and two component blends and Duncan's Multiple Range Test for three component blends was considered for separation.

3. Results and discussion

3.1 Micronutrients contents of raw materials

Minerals (iron, sodium and potassium) and beta-carotene contents of food raw materials FCM, SBF and MOLP were analysed and the results are presented in Table 3. Prior analysis before blending was necessary for estimating quantities used during fortification of mchuchume so that consumption of reasonable amount of developed product could feed a human body with micronutrients that meet Recommended Dietary Allowances (RDAs) of children and women at reproductive age.

Table 3

There was a significant difference ($p<0.05$) of iron contents in the three food materials. The iron content found in FCM was lower compared to that reported in raw cassava; 0.01 g kg^{-1}, 0.10 g kg^{-1} and 0.12 g kg^{-1} by Oluyemi *et al.*[20], Oyedeji[21] and Adeniji *et al.*[22], respectively.
Iron content observed in FCM was below recommended dietary allowances (0.05 - 0.28 g day^{-1}).[35] Lack of iron in cassava and its related products that could meet levels of recommended dietary allowance had previously reported and ascribed to its unavailability to crops because in the soil it forms highly insoluble ferric compounds[23]. The iron values found in this study for SBF and MOLP were comparable to 0.04 – 0.12 g kg^{-1} reported by Eshun[24] and 0.30 – 0.51g kg^{-1} by Emelike *et al.*[25], respectively. The differences might have been caused by geographical location and preparation methods.
Values of sodium observed in the three food materials differed significantly ($p < 0.05$) and MOLP was a better source of sodium than FCM and SBF. Sodium values observed in SBF and MOLP agreed with that reported by Eshun[24] and Moyo *et al.*[14], respectively while that in FCM were found marginally to findings (0.05 – 0.26 g kg^{-1}) reported in 5 cassava genotypes by Charles *et al.*[26]
Statistical analysis indicated significant difference ($p < 0.05$) for potassium contents in the three food materials. The observed potassium content in FCM were lower compared to 4.58 – 6.23 g kg^{-1} reported by Rojas *et al.*[27] in raw cassava but slightly higher to some values reported in ten samples of cassava flours (0.21 – 1.95 g kg^{-1}) by Gomes *et al.*[28] Potassium level in SBF differed slightly to findings (23.58 g kg^{-1}) reported by Garcia *et al.*[29] probably due to differences in the variety of seeds used and the climate conditions. Potassium in MOLP was lower compared to the values (11.20 – 22.90 g kg^{-1}) published by Ali *et al.*[30] Minerals in dry weight basis (Fe, K and Na) observed in FCM were lower in comparison to that of raw cassava reported in literatures.[3] This could be part of losses encountered during fermentation.
β-carotene was detected in MOLP but values in FCM and SBF were below the limit detection of instrument (0.2×10^{6} g mL^{-1}). In the works of Akinwale *et al.*[31] and Lokuraka[32] it is stated that white fleshed cassava and soya bean flour have negligible β-carotene. On the other side, β-carotene in the MOLP was fairly in agreement with the values previously reported by Ali *et al.*[30] and Sabina *et al.*[33] The high β-carotene content found in MOLP suggests its applicability in managing vitamin A eye blindness when consumed either alone or as supplement in fortified foods.

3.2 Micronutrient contents of mchumchume produced from Cassava-Soya and Cassava-Moringa leave blends

The contents of minerals (iron, sodium and potassium) and β-carotene, g kg^{-1} dry weight basis analysed in samples of two components fortified mchuchume are presented in Table 4. Iron and potassium contents of CS1 blend made of FCM: SBF (65:35) increased significantly ($p < 0.05$) by 3472% and 408%, respectively relative to the control. Unexpectedly, the blending caused significant decrease of sodium ($p < 0.05$) by 24% relative to the control. β-carotene was below the limit detection of instrument ($< 0.2 \times 10^{-6}$ g/mL). The CS2 (FCM: SBF 85:5) had iron and potassium content increased significantly ($p < 0.05$) by 1468% and 175%, respectively. Sodium decreased significantly ($p < 0.05$) by 10% relative to the control. B-carotene was again below the limit detection of instrument ($< 0.2 \times 10^{-6}$ g/mL).

Table 4

The findings indicated that the SBF used in fortification had higher amounts of iron and potassium while sodium was lower than that of the control. Undetected β-carotene continued to supports the findings of the above section and confirmed the report of Akinwale *et al*.[31] and Lokuraka[32] that white fleshed cassava and soya been have negligible β-carotene. In the CM1 made of 15% MOLP substitution, the values for iron, sodium and potassium were significantly increased ($p < 0.05$) by 6914%, 276% and 240%, respectively relative to the control and the detected β-Carotene was 0.02 g kg^{-1}. The CM2 contained 5% MOLP substitution, the values of iron, sodium and potassium were significantly increased ($p < 0.05$) by 2281%, 92% and 75%, respectively relative to the control. This sample had β-Carotene value of 0.01 g kg^{-1}.

These results still asserted that using MOLP during fortification elevates amounts of iron, potassium and sodium in the control samples. Detected β-carotene supports the findings of the previous section and concludes MOLP being good source of β-carotene. Minerals and β-carotene in the two component blends increased with the degree of supplementation and concurred to observation reported by Fashakin[9], Adeniyi *et al*.[1] and Sikuku *et al*.[34] except sodium which decreased in the CS blends on course of supplementation.

When CS1 or CM1 is eaten a day at 100 g as serving size by children aged 0 - 5 months highest recommended dietary allowance (RDA) of iron met will be 44% or 86%, respectively, RDA of sodium met will be more than 100% or more than 100%, respectively while that of potassium will be 43% or 64%, respectively. These foods when consumed by girls (15 – 18 years) and women (19 - 49 years) the highest iron, sodium and potassium RDA met will be 21% or 40%, more than 100% or more than 100% and 10% or 15%, respectively.

The results reflect that consumption of CS blends can accelerate vitamin A deficiency in children and women of reproductive age. This is because they contained undetectable β-carotene and thus could not meet RDA for Vitamin A of either specified group. CM1 can make children to meet 82% of vitamin A RDA while girls and women acquire 55% of the vitamin A RDA.[35]

3.3 Micronutrients of Cassava-Soya-Moringa samples

Minerals (iron, sodium and potassium) and β-Carotene in g kg^{-1} dry weight basis for the blends are shown in Fig. 1. There was significant increased ($p < 0.05$) of iron, sodium and potassium relative to the control. β-carotene detected ranged from 0.01 to 0.02 g kg^{-1}. Iron was 0.03 to 0.09 g kg^{-1}, sodium, 0.17 to 0.35 g kg^{-1} and potassium, 3.59 to 7.42 g kg^{-1}.

Fig. 2

Addition of both SBF and MOLP to FCM increased the contents of iron, sodium and potassium in the CSM blends. These factors raised the β-carotene content in the CSM blends to the detectable levels. The effect of collaborative fortification was also supported by spread of percentage increased iron, sodium and potassium in CSM blends that were 3784% to 10656%, 69% to 256% and 254% to 633%, respectively against the increase observed in the two components blends (1468 to 6914%, -10 to 276% and 75 to 408%, respectively). Mixing ratios influenced micronutrient composition observed in the blends. Trends for increase in amount of potassium during fortification complied with degree of supplementation because both SBF and MOLP had high level of potassium than that in unfortified FCM. β-carotene in the CSM blends increased when the amount of MOLP increased. MOLP was the only source since β-carotene was not detected in SBF and FCM during analysis. The increase of potassium and β-carotenes during supplementation in the present study was comparable to what observed in the related research conducted by Samuel *et al*.[36] Iron and sodium enrichment did not depict a clear increasing trend relative to degree of supplementation. This might have been ascribed by the initial quantities present in the food raw materials.

In human nutrition iron is a vital part of red blood cells that carry and release oxygen and has a function to manage iron deficiency anaemia. Sodium is needed by human body for maintain normal blood pressure and normal function of muscles and nerves. Potassium deficit in human is an intolerable because it is an ingredient in blood cell and tissue formation, balances acid-base condition, as K^+, transfers impulse during coordination and enhances contraction of muscles. In addition, recent studies show that potassium can help to reduce a risk of stroke.[37]

β-carotene is utilized by the human body after its oxidative cleavage into retinal. It plays a major role in the formation of eye molecules involved in light absorption for vision. It also plays an important role in bone growth and health of the immune system.[30] Therefore, presence of iron, sodium, potassium and β-carotenes in CSM blend make it prerequisite dietary component of human nutrition.

The CSM 10 with 56: 29: 15 Cassava-Soya-Moringa mixing ratio was found to be micronutrient densest blend among others formulated. When it is consumed daily at 0.1 kg as serving size by children aged 0 - 5 months, the highest iron, sodium, potassium and vitamin A RDA met is more than 100%, more than 100%, 84% and 86%, respectively. The same foods when consumed by girls (15 – 18 years) and women (19 - 49 years) the highest iron, sodium potassium and vitamin A RDA met will be 58%, more than 100%, 19% and 57%, respectively.

3.4 Bioefficacy of extruded Soya beans and blanched sun dried *Moringa oleifera* leaves

Food bioefficacy refers to relative ability of a food to produce desired constituents in a biological environment. It can be improved through enhanced bioavailability. Cassava-Soya-Moringa (CSM) blends development adhered to fundamental nutritional principles that if a nutrient is present in a food it should be digestable, bioavailable or bioaccessible. Davidsson *et al*.[38] and Merwe *et al*.[39] demonstrated that bioavailability and bioaccessibility of various minerals such as iron and zinc contained in soya bean and *Moringa oleifera* can be increased by removal of antintritional factors which is possible through improved processing like in the use of appropriate enzymes, application of heat or increasing the content of ascorbic acid. Gopalakrishnan *et al*.[40] reported that *Moringa oleifera* leaves powder has approximate 0.17 g kg^{-1} vitamin C dry basis. While cooking can increase iron bioavailability of certain vegetables 2 to 10 times[15], ascorbic acid can overcome some of the inhibitory effects of phytate and phenolic compounds on non-haem iron bioaccessibility.[39] Therefore, simultaneous inclusion of extruded soya bean flour processed by high temperature short time (HTST) technology and *Moringa oleifera* leaves powder processed through blanching and sun drying in "*Mchuchume*" gives synergistic impacts that advocate a sustainable intervention strategy for iron and vitamin A deficiencies.

4. Conclusion

This study has addressed a potentially viable alternative to conventional fortification in rural parts of Africa where the communities rely predominantly on their own produce and raw food stuffs purchased at local markets. The study showed that simultaneous inclusion of soya bean flour and *Moringa oleifera* leaves powder provides enough iron and β-carotene in "mchuchume". Factors such as high temperature short time extrusion cooking of soya bean and *Moringa oleifera* leaves would likely to enhance the bioavailability and bioaccessibility of iron and zinc contained in Cassava-Soya-Moringa (CSM) blends. Consumption of CSM blends would provide recommended dietary allowances that could largely decrease iron and β-carotene deficiencies. This is because the three raw materials used for blending are available, affordable and sustainable to the community. The raw materials are palatable however; palatability of the blends produced should be deduced from studies on the sensory and physical attributes. All the CSM blends are recommended nutritious food products that can enhance household food and nutrition security among cassava consuming populations.

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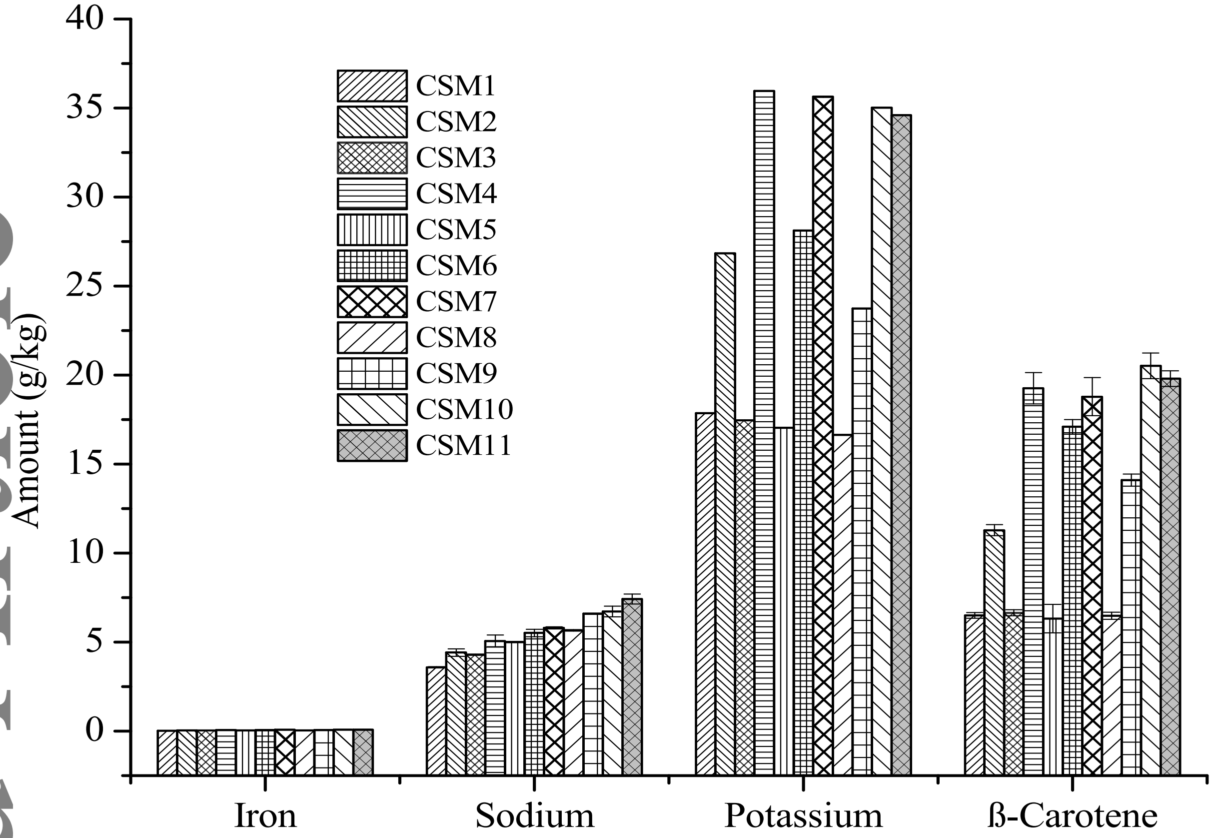

Fig. 1: Micronutrient composition of tree component Cassava-Soya-Moringa, CSM mixture. Mixing ratios are CSM1= 80:15:05, CSM2 = 74: 16:10, CSM3 = 74:21:05, CSM4 = 70:151:15, CSM5 = 68: 27:05, CSM6 = 65:24:11, CSM7 = 65:20:15, CSM8 = 62:33:05, CSM9 = 56:35:09, CSM10 = 56:29:15 and CSM11= 50:35:05.

Table 1: Formulations for two component blends

Sample name	Code	Mixing ratio
Cassava-soya (maximum)	CS1	65:35
Cassava-soya (minimum)	CS2	85:15
Cassava-moringa (maximum)	CM1	85:15
Cassava-moringa (minimum)	CM2	95:5

Table 2: Ratios for formulations of three component blends from the design expert software

Runs	Sample Code	Mixing ratio							
1	CSM1	80%	FCM	:	15%	SBF	:	05%	MOLP
2	CSM2	74%	FCM	:	16%	SBF	:	10%	MOLP
3	CSM3	74%	FCM	:	21%	SBF	:	05%	MOLP
4	CSM4	70%	FCM	:	15%	SBF	:	15%	MOLP
5	CSM5,	68%	FCM	:	27%	SBF	:	05%	MOLP
6	CSM6	65%	FCM	:	24%	SBF	:	11%	MOLP
7	CSM7	65%	FCM	:	20%	SBF	:	15%	MOLP
8	CSM8	62%	FCM	:	33%	SBF	:	05%	MOLP
9	CSM9	56%	FCM	:	35%	SBF	:	09%	MOLP
10	CSM10	56%	FCM	:	29%	SBF	:	15%	MOLP
11	CSM11	50%	FCM	:	35%	SBF	:	05%	MOLP

FCM, Fermented cassava meal, SBF, Soya beans flour and MOLP, *Moringa oleifera* leaves flour CSM, Cassava-Soya-Moringa; Mixing ratios are 1= 80:15:05, 2 = 74: 16:10, 3 = 74:21:05, 4 = 70:151:15, 5 = 68: 27:05, 6 = 65:24:11, 7 = 65:20:15, 8 = 62:33:05, 9 = 56:35:09, 10 = 56:29:15 and 11= 50:35:05.

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Table 3 Micronutrient composition of the raw materials

Samples	Minerals (g kg^{-1})			Vitamin g kg^{-1}
	Iron	Sodium	Potassium	β-Carotene
FCM	0.001^a ± 0.00	0.10^a ± 0.02	1.01^a ± 0.09	< 0.2 x 10^{-6} g/mL
SBF	0.09^b ± 0.01	0.03^a ± 0.00	12.82^b ± 0.28	< 0.2 x 10^{-6} g/mL
MOLP	0.39^c ± 0.05	1.90^b ± 0.02	17.24^c ± 0.80	16.81 ± 2.40

All values are presented in per 100g dry matter of edible food, mean ± standard deviation. Means followed by the same superscripts within a column do not differ significantly ($p > 0.05$). FCM, Fermented cassava meal, SBF, Soya beans flour and MOLP, *Moringa oleifera* leaves flour.

Table 4 Micronutrients composition of Mchuchume fortified with soya bean flour and *Moringa oleifera* leaves powder, respectively.

Samples	Minerals (g kg^{-1})			Vitamin g kg^{-1}
	Iron	Sodium	Potassium	β-Carotene
CS1	$0.03^{de} \pm 0.00$	$0.07^{d} \pm 0.01$	$5.14^{d} \pm 0.09$	< 0.2 x 10^{-6} g/mL
CS2	$0.01^{df} \pm 0.00$	$0.09^{ad} \pm 0.01$	$2.78^{e} \pm 0.07$	< 0.2 x 10^{-6} g/mL
CM1	$0.06^{e} \pm 0.01$	$0.36^{f} \pm 0.00$	$3.45^{f} \pm 0.12$	$19.79^{b} \pm 1.45$
CM2	$0.02^{f} \pm 0.00$	$0.19^{g} \pm 0.01$	$1.77^{g} \pm 0.15$	$6.30^{c} \pm 0.45$

Mean ± standard deviation. Means followed by the same superscripts within a column do not differ significantly ($p > 0.05$). FCM, Fermented cassava meal, SBF, Soya beans flour, MOLP, Moringa oleifera leaves flour, CS, Cassava–Soya and CM, Cassava-Moringa blends. Mixing ratios are CS1 = 65:35, CS2 = 85:15, CM1 = 85:15, and CM2 = 95:5.