Development and Evaluation of Organoleptic Quality and Acceptability of Cassava-based Composite Crackers for Supplementing Primary School Children

***T. C. E. Mosha, M. A. Sadick and H. S. Laswai**

Department of Food Science and Nutrition,
Sokoine University of Agriculture,
P. O. Box 3109, Morogoro, Tanzania

Abstract

The study involved formulating cassava-based fortified composite novel products for boosting nutrient uptake of primary school children. Thirteen cassava-based crackers were prepared from blends of extruded cassava, bean, wheat and soybean flours on a replacement basis. Proximate, amino acids and mineral compositions were determined to evaluate the potential of the crackers to supply energy and nutrients required for optimal growth and cognitive function. Results showed that, protein content in the composite crackers ranged from 3.35 g/100g in plain cassava crackers (CC) to 31.54-g/100 g in cassava-soybean cracker (CSC1), while energy density ranged from 416 kcal in cassava-bean-soybean-wheat cracker (CBSWC) to 461 kcal in CSC1. Amino acid scores ranged from 32 to 66% with Lysine, Leucine and Threonine as the most limiting amino acids. The concentrations of Fe, Mg, Cu, Zn and Ca were within the recommended intake levels for primary school children. Organoleptically, the cassava-soybean-wheat cracker (CSWC) was ranked highest in colour, smell and texture while the cassava-soybean cracker (CSC4) was superior in terms of taste and appearance. Overall, all the cassava-based composite crackers were accepted by the panellists. The fortified cassava-bean-soybean composite crackers therefore have a potential for use as supplementary foods to increase protein, energy and mineral intake of primary school children in Tanzania.

Introduction

Under-nutrition is among the major constraints to both 'Education for All' and the Millennium Goals of achieving universal primary education. A large group of schoolchildren, perhaps over half, are underfed, and poorly nourished (WHO, 2002). Under-nutrition associated with inadequate energy intakes is common in many developing countries and micronutrient deficiencies, such as iron, iodine and vitamin A deficiencies are becoming a serious problem for schoolchildren. These nutritional problems adversely affect schoolchildren's attendance, scholastic performance and concentration in class (UNICEF, 2003). An understanding and awareness of the heavy burden of malnutrition and disease among schoolchildren in developing countries is growing because nutritional and health status influence the child's learning and overall performance in school (Legge, 2002). Poor nutrition among school-age children diminishes their cognitive development either through physiological changes or by reducing their ability to participate in learning experiences (Partnership in Child Development, 2002). This paradigmatic shift in our understanding of the role of health and nutrition in schoolchildren has fundamental implications for the design of effective interventions that utilize locally available resources (USAID, 2000). Improving the health and nutrition of schoolchildren through school feeding programmes is not a new concept. School health programmes are ubiquitous in high-income and most middle-income countries. In low-income countries, these programmes were a common feature in the early colonial education systems, which focused on clinical diagnosis and treatment and on elite schools in urban centres (Liddel and Rae, 2001).

The majority of the schoolchildren in Tanzania perform poorly in schools and many dropout of school due to nutrition and health related problems (FAO, 2007). According to FAO (2007), 22% of

**Corresponding author: T.E.C. Mosha*

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school age children in Tanzania are stunted owing to chronic inadequate intake of energy and other nutrients. In children, energy and micronutrient deficiencies reduce resistance to infectious diseases, retard growth and reduce concentration and comprehension abilities resulting in poor performance in school. Most children in rural schools do not receive mid-morning breakfast unlike their counterparts in urban schools, who can afford to buy snacks from street vendors during the mid-morning recess (FAO, 2007). According to literature, a person who skips breakfast will not be able to meet the day's energy and other nutrient requirements [Pollitt and Mathews, 1998; Benton and Parker, 1998; Jacoby *et al.,* 1996). This implies that, breakfast and mid-morning snacks influence the nutritional status and school performance of schoolchildren.

Although wheat-based bakery products have been universally considered as the most ideal, in countries where climatic conditions do not allow cultivation of wheat or imported wheat is unaffordable, production of bakery products from 100% wheat flour is impractical. This situation has prompted efforts to find substitutes for wheat in producing various bakery products. The use of composite flours in making bakery products has been widely researched (McWatters *et al*., 2003). Cassava is one of copious food crop that grows in most areas of Tanzania, but is under-utilized (Mlingi and Ndunguru, 2003). Although cassava generally lacks the essential nutrients for active and growing children, it is rich in energy, affordable and readily available. Formulating cassava-based snacks that are enriched with bean and/or soybean protein and fortified with micronutrients could provide a well-balanced nutritious supplement for schoolchildren, especially rural primary schools. According to WHO (2002), WHO/UNICEF, (1998) and Dewey and Brown (2003), developing nutrient-dense, fully cooked, ready-to-eat, inexpensive supplementary foods from locally grown food ingredients using suitable household-level or small-to-medium scale production technologies in community settings has been strongly recommended as a viable and sustainable approach to address the problem of under-nutrition in low income countries. Centrally processed, fortified and ready-to-eat low-cost foods would provide a reliable option for many families and can thus contribute immensely in ameliorating the problem of protein-energy and micronutrient under-nutrition among young children. Such foods must be nutritionally sound to provide the essential amino acids needed for growth and the processing methods used should insure maximum retention of the essential nutrients. Furthermore, the products must be organoleptically acceptable to consumers and shelf stable to allow ample time for transportation, storage, and marketing while still maintaining their nutritional and sensory wholesomeness (WHO/UNICEF, 1998; Dewey and Brown, 2003).

Powell *et al*., (1989) reported that, school snack programme provides about 10 – 30% of the daily nutritional requirements, depending on the target nutrient. For certain nutrients such as iron, 100% of recommended daily intake may be attained. Crackers have been suggested as the best bakery product for school snacks due to their ready-to-eat form, high nutritional value, high acceptability, relatively long shelf life and good eating quality (McWatters, 2003). Composite crackers with high sensory ratings have been produced from blends of millet/pigeon pea flour (Eneche, 1999), green gram, bengal gram, black gram and wheat (Sigh *et al.,* 1989), groundnuts, cowpea and wheat (Sigh, 1991) and soybean/chickpea with wheat (Hegazy and Faheid, 1990). It is therefore envisaged that, development of convenient supplementary snacks from blends of cassava, soybean, and/or bean flours with wheat would offer an immediate breakthrough in addressing under-nutrition among primary school children in low-income countries. The objective of this study was to develop and evaluate the physical characteristics, nutritional value, sensory quality and acceptability of cassava-bean/soybean composite crackers for supplementing primary school children.

Materials and methods

Materials: The snack formulated in this study was prepared from following materials, cassava (Manihot esculenta), red beans (Phaseolus vulgaris), wheat (Triticum aestivum) and soybeans (Glycine max). Samples of sweet cassava roots were obtained from the Program for Agricultural and Natural Resources Transformation for Improved Livelihoods (PANTIL) cassava project pilot villages in Muheza (Tongwe) and Kibaha (Mikongeni) districts, Tanzania, while beans were obtained from the Bean/Cowpea Collaborative Research Support Program project at Sokoine University of Agriculture, Morogoro, Tanzania. Wheat and soybean flours were purchased from the retail shops in Morogoro town. Mineral and vitamin premixes were purchased from Dyets Inc. (Bethlehem, PA, USA). Margarine, baking powder, iodised salt and sugar were procured from a local supermarket in Morogoro town, Tanzania.

Methods: Sample preparation. Fresh cassava roots were sorted to remove extraneous matter, peeled, washed in distilled water and then soaked for 6 hours in water to remove the mucilage and reduce hydrocyanide.The cassava was then chipped to approximately 0.2-0.5 cm width, 1-5 cm length and 0.1-0.4 cm thick using a chipping machine (Model CH, Intermech Engineering, Morogoro). Chips were then sun-dried for 48 hours. The dried chips were then milled with a commercial hammer mill (Model HM, Intermech Engineering, Morogoro) into fine flour (screen size 0.8 mm). The beans were sorted and winnowed to remove extraneous materials, washed in cold water, sun dried for eight hours to attain moisture content of less than 14%. The beans were thereafter ground to a fine powder (screen size 0.8 mm). The experimental composite crackers were formulated in the laboratory of the Department of Food Science and Technology, Sokoine University of Agriculture following Rhona (1983) and Eyedu (2000) methods (Table 1). The composite crackers developed were plain cassava cracker (CC), cassava-soybean crackers (CSC1), (CSC2), (CSC3), (CSC4), cassava-wheat cracker (CWC), plain wheat cracker (WC), cassava-bean-wheat crackers (CBWC1), (CBWC2), cassava-bean-soybean-wheat crackers (CBSWC1), (CBSWC2), (CBSWC3), and cassava-soybean-wheat cracker (CSWC). The various ratios were made to optimise the energy density, protein and amino acid scores as recommended by FAO/WHO/UNU (1985) for school-age children.

Chemical analyses: The nutritional composition of the composite crackers was determined according to the standard AOAC (1995) procedures. The moisture content was determined in triplicate by oven drying method 930.15. Protein was determined by Kjeldahl method 920.87 using 6.25 as the conversion factor. Fat was determined by Soxhlet Ether extraction method 920.85. The ash content was determined by using dry ashing methods 923.03 and fibre contents were determined by using method 920.86. Carbohydrate content was calculated by difference while gross energy was determined by calculation from the fat, protein and carbohydrate values by using the Atwater factors of 9, 4 and 4, respectively. Amino acids were computed by using the USDA National Nutrient Database for Standard Reference (USDA, 2008). The amino acid scores were obtained by comparing the crackers' essential amino acids with the FAO/WHO/UNU (1985) reference patterns for pre-school age children. The essential amino acids reference pattern for pre-school age children was His 19, Ile 28, Leu 66, Lys 58, SAA (Met+Cys) 25, AAA (Tyr+Phe) 63, Thr 34, Trp 11 and Val 35 (FAO/WHO/UNU, 1985). Minerals - Ca, Fe, Cu, Mg, Mn and Zn were determined by using UNICAM Atomic Absorption Spectrophotometer (Model 919, Cambridge, U.K.). A single mineral hollow cathode lamp was used for each element.

Sensory evaluation

The crackers were placed in identical glass bowls coded in three digit numbers and presented to a panel of 60 students (20 university students aged 21 – 35 years and 40 primary school pupils aged 9 – 15 years). Panellists were requested to test each product, one at a time and rank them in terms of appearance, aroma, colour, taste, and mouth feel. After testing each product, the panellists were required to rinse their palate with distilled water before testing the next product. To avoid fatigue on the panellists, the products were divided into two groups, which were tested on different days. The panellists expressed their preference for the products on a 5-point Hedonic scale, whereby; scores of five and one represented the highest and lowest order of preference, respectively (larmond, 1977).

Statistical analysis

The data for proximate composition, amino acids, mineral concentrations and sensory quality attributes of the various composite crackers were subjected to Analysis of Variance (ANOVA) using SAS (Statistical Analysis System) program (Version 8) for Windows®. A difference was considered to be significant at $p<0.05$. Means were separated by using

Table 1: Composition (g/100 g) of the crackers

Ingredients	Cracker[1]												
	CC	CSC1	CSC2	CSC3	CSC4	CWC	WC	CBWC1	CBWC2	CBSWC1	CBSWC2	CBSWC3	CSWC
Cassava	73.04	14.61	51.13	43.82	36.52	14.61	0.00	43.82	36.52	29.22	43.82	29.22	25.56
Bean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.30	18.26	10.96	3.65	7.30	0.00
Soybean	0.00	58.43	21.91	29.22	36.52	0.00	0.00	0.00	0.00	10.96	14.61	7.30	25.56
Wheat	0.00	0.00	0.00	0.00	0.00	58.43	73.04	21.91	18.26	21.91	10.96	29.22	21.91
Minerals premix	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Baking soda	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt (iodised)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Margarine	18.26	18.26	18.26	18.26	18.26	18.26	18.26	18.26	18.26	18.26	18.26	18.26	18.26
Sugar	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.00	100.00	100.00	100.00	100.00	100.00

1CC = plain cassava cracker; CSC = cassava-soybean cracker; CWC = cassava-wheat cracker; WC = plain wheat cracker; CBWC = cassava-bean-wheat cracker; CBSWC = cassava-bean-soybean-wheat cracker; CSWC = cassava-soybean-wheat cracker

the Duncan's Multiple Range Test (DMRT).

Ethical Clearance

Approval to use human subjects was obtained from the Ethical Committee of the National Institute for Medical Research. All panelists and parents/guardians of the school-age children who participated in the study signed a consent form to affirm their willingness to participate or allow their children to participate in the test panel. The panelists and the schoolchildren had the liberty to decline participation or withdraw from the test panel at any stage without being persecuted.

Results and discussion

The physical characteristics of the crackers namely thickness, diameter, spread ratio (diameter/thickness), and weight of the composite crackers are shown in Table 2. Individual cracker thickness ranged from 0.64 to 0.82 cm with the CSC1, CSC3, CSC4, CWC, CBWC1, CBWC2, CBSWC1, CBSWC2 and CSWC crackers being similar to the plain wheat cracker (WC). The thickest cracker was the plain cassava (CC) while the thinnest crackers were CSC2 and CBSWC3. The spread ratios for all the crackers were similar to that of the plain wheat (control) cracker (WC), which ranged from 8.19 to 8.63. Individual cracker weights ranged from 15.18 to 17.49 g with the CC, CSC1, CSC3, and CBWC1 crackers having similar weight to the plain wheat (control) cracker. The lightest crackers were CSC2, CBSWC1 and CSWC. The crackers that were lightest also contained higher proportions of beans and/or soybeans, which made the composites, lose more water during baking. Hoojat and Zebik (1984) observed that, replacement of wheat flour by 20% navy bean flour or 30% sesame seed flour in the preparation of cookies reduced the weight of the whole-wheat flour cookies. In general, cassava-bean-soybean flour composites compared flawlessly with the control cracker (WC) in thickness, diameter, spread ratio and weight. This implied that, the composite crackers had the required physical qualities for commercial products.

The proximate composition of the composite crackers is presented in Table 3. Protein content in the crackers ranged from 3.35-g/100 g in plain cassava cracker (CC) to 31.54-g/100 g in CSC1. Plain cassava crackers (CC) contained 3.35-g/100 g protein, but the protein content increased to 31.5 g/100 g and 20.9 g/100 g when cassava was replaced by 80% (CSC1) and 50% (CSC4) soybean, respectively. According to FNB-IOM (2003), the recommended protein requirement for school-age children (5 – 13 years) is 19 – 34 g per day based on

Table 2: Mean values for thickness, diameter, spread ratio and weight of the composite crackers

Cracker[3]	Physical characteristics[1,2]			
	Thickness (cm)	Diameter (cm)	Spread ratio	Weight (g)
WC (control)	0.76±0.01[bc]	6.07±0.01[b]	8.19±0.19[a]	17.31±2.19[a]
CC	0.82±0.00[a]	6.68±0.03[a]	8.63±0.00[a]	17.49±2.80[a]
CSC1	0.71± 0.00[c]	6.05±0.00[b]	8.63±0.00[a]	17.22±2.09[a]
CSC2	0.66±0.01[d]	5.66±0.18[c]	8.61±0.25[a]	15.18±0.85[c]
CSC3	0.74±0.01[c]	6.12±0.01[b]	8.38±0.25[a]	17.35±2.19[a]
CSC4	0.79±0.01[ab]	6.65±0.07[a]	8.50±0.62[a]	16.80±1.46[b]
CWC	0.76±0.00[bc]	6.30±0.00[b]	8.28±0.18[a]	16.32±2.43[b]
CBWC1	0.74±0.01[c]	6.02±0.01[b]	8.38±0.30[a]	17.34±2.19[a]
CBWC2	0.71±0.00[c]	6.05±0.00[b]	8.48±0.00[a]	16.21±1.31[b]
CBSWC1	0.71±0.00[c]	6.05±0.00[b]	8.45±0.01[a]	15.93±1.14[c]
CBSWC2	0.71±0.00[c]	6.05±0.00[b]	8.46±0.04[a]	16.23±1.40[b]
CBSWC3	0.64±0.01[d]	5.25±0.09[d]	8.28±0.13[a]	16.23±1.50[b]
CSWC	0.71±0.00[c]	6.07±0.01[b]	8.45±0.05[a]	15.93±1.14[c]

[1] Means ± SD based on three analyses.
[2] Means within a column with different superscripts are significantly different at p<0.05.
[3] CC = plain cassava cracker; CSC = cassava-soybean cracker; CWC = cassava-wheat cracker; WC = plain wheat cracker; CBWC = cassava-bean-wheat cracker; CBSWC = cassava-bean-soybean-wheat cracker; CSWC = cassava-soybean-wheat cracker.

0.95 g/kg/day). Consumption of 100 g of crackers e.g. CSC1 or CSC4 would provide more than 100% of the daily requirement for protein for school-age children. Fat concentration in the composite crackers ranged from 12.04 g/100 DM in plain cassava flour cracker to 30.06-g/100 g DM in cassava-soybean crackers (CSC1). According to the FNB-IOM (2003), the recommended fat intake for school-age children aged 5 – 13 years is 30 g per day. Consumption of 100 g of crackers would thus provide 24.08 – 60.12 g of fat, which is about 80 – 200% of the recommended daily intake for fat. In this regard, the fat content in some of the cassava-soybean composite crackers was higher ($p<0.05$) than the recommended daily fat intake for primary schoolchildren by 1.9 – 100%. Although human body requires dietary fat and essential fatty acids for normal growth and development, USDA (1995) recommends that, schoolchildren should consume no more than 30% of calories from fat, with no more than 10% of calories derived from saturated fat.

Fibre is an important dietary component in the diet for enhancing bowel movement, preventing overweight, constipation, reducing the risk of cardiovascular diseases, diabetes, and colon cancer (Whitney *et al.,* 1990). The crude fibre content of the composite crackers ranged from 7.26-g/100 g DM in plain cassava (CC) cracker to 18.43 g/100 g DM in cassava-soybean cracker (CSC1). Higher fibre contents were observed in crackers containing high proportions of soybean flour, e.g. CSC4 and CSWC. FNB-IOM (2003) recommends a daily fibre intake of 25 – 31 g as ideal for school age children aged 5 – 13 years. Consumption of 100 g of crackers per day would provide 14.2 – 36.85 g of fibre, which is about 57 – 119% of the recommended daily intake for fibre. Selection of composite crackers containing high proportions of bean/soybeans is therefore of advantage in obtaining dietary fibre.

Carbohydrate content of the crackers ranged from 16.09-g/100 g DM in cassava-soybean cracker (CSC1) to 74.84-g/100 g DM in plain cassava crackers (CC). Carbohydrate concentration in the various composite crackers differed significantly ($p<0.05$). Plain cassava cracker (CC) contained the highest concentration of carbohydrates (74.86 g/100 g DM) followed by CWC (64.65 g/100 g DM), CWC (62.18 g/100 g DM), and CWBC2 (60.64 g/100 g DM) (Table 2). According to FNB-IOM (2003), the recommended daily intake of carbohydrate for school-age children (5 – 13 years) is 130 g. Consumption of 100 g crackers per day would provide 32 - 148 g of carbohydrate, which is about 25 – 114% of the recommended daily intake for carbohydrates. Composite crackers containing high proportions of cassava appeared to have high concentration of carbohydrate since cassava is a rich source of carbohydrate compared to beans and soybeans (Ebuehi *et al.*, 2005). Energy is important for schoolchildren because it increases the attention span, concentration and comprehension of pupils in class. According to FNB-IOM (2003), the

Table 3: Proximate composition (g/100 g) and energy content (kcal/100 g) of the various cracker formulations1,2

Cracker3	Ash	Protein	Fat	Fibre	Carbohydrate	Energy (kcal)
CC	2.49±0.01e	3.35±0.24h	12.04±0.13h	7.26±0.21ef	74.86±0.16a	421.17±1.50ef
CSC1	3.87 ± 0.18a	31.54±1.41a	30.06±0.41a	18.43±0.72a	16.09±0.10k	461.10±1.52a
CSC2	3.25±0.14bcd	12.15±0.48e	19.79±0.46cd	16.21±0.98ef	48.59±1.14g	421.12±6.76ef
CSC3	3.71±0.02a	16.88±0.09c	20.83±1.11c	16.95±0.23ef	41.62±0.94i	421.51±6.55ef
CSC4	3.84±0.05a	20.92±0.82b	22.62±0.88b	15.78±0.42cd	36.82±0.32j	434.59±5.88cd
CWC	2.47±0.07e	5.93±0.54g	17.32±0.89f	9.63±0.40bc	64.65±0.02b	438.19±5.76bc
WC	2.32±0.05e	6.33±0.86g	18.98±0.48de	9.56±0.75b	62.81±0.41c	447.42±0.79b
CBWC1	3.08±0.02d	9.64±0.36f	16.82±0.51f	8.97±1.03cd	61.48±1.20d	435.92±1.66cd
CBWC2	3.11±0.01d	11.77±0.49e	15.29±0.19g	9.19±0.17cdef	60.64±0.15d	427.27±0.29cdef
CBSWC1	3.44±0.01bc	15.10±0.21d	19.87±0.86cd	15.34±0.51def	46.25±0.15h	424.23±6.32def
CBSWC2	3.48±0.01b	14.47±0.56d	17.92±0.44ef	13.52±0.32ef	50.61±0.34f	421.61±3.06ef
CBSWC3	2.32±0.01e	13.04±0.79e	15.01±1.21g	12.40±0.66f	57.23±0.24e	416.17±8.71f
CSWC	3.22±0.26d	18.02±0.08c	19.65±0.59cd	13.33±0.58cde	45.77±0.17h	432.05±6.27cde

1 Means ± SD based on three analyses.
2 Means within a column with different superscripts are significantly different at p<0.05.
3 CC = plain cassava cracker; CSC = cassava-soybean cracker; CWC = cassava-wheat cracker; WC = plain wheat cracker; CBWC = cassava-bean-wheat cracker; CBSWC = cassava-bean-soybean-wheat cracker; CSWC = cassava-soybean-wheat cracker

recommended daily intake of energy for school-age children (5 – 13 years) is 1715 kcal. The energy content per 100 g of the composite crackers ranged from 416 kcal in CBSWC to 461 kcal in CSC1. This implied that, consumption of 100 g of crackers per day would provide 416 – 461 kcal, which is about 24 – 27% of the recommended daily intake for calories (1715 kcal).

Table 4 data show the amino acid profile of the various composite crackers and the proportions of the constituent essential amino acids to the FAO/WHO/UNU (1985) reference patterns for pre-school and school-age children. Proportionality pattern of essential and non-essential amino acids in foods is the most important determinant of protein quality FAO/WHO (1991). The greater the proportion of the essential amino acids, the greater is the biological quality. Proteins that are deficient in one or more of the essential amino acids are of poor quality and this is usually reflected in their amino acid scores. All the composite crackers except the CC, WC, CBWC1, CBWC2 and CBSWC3 had amino acid patterns that were considered acceptable for school age children i.e. His 19, Ile 28, Leu 66, Lys 58, SAA (Met+Cys) 25, AAA (Tyr+Phe) 63, Thr 34, Trp 11 and Val 35 g per kg.

Threonine concentrations in the composite crackers ranged between 44 and 91% of the FAO/WHO/UNU (1985) recommended amount for pre-school and school-age children (34 g/kg crude protein), while for tryptophan, the concentrations in the various composite crackers as a proportion of the FAO/WHO/UNU (1985) recommendation for pre-school and school-age children (11 g/kg crude protein) were CC (91%), CSC1 (109%), CSC2 (100%), CSC3 (100%), CSC4 (100%), CWC (82%), WC (82%), CBWC1 (91%), CBWC2 (91%), CBSWC1 (91%), CBSWC2 (91%), CBSWC3 (91%) and CSBC (91%). The concentrations of lysine in the various crackers as a proportion of the FAO/WHO/UNU (1985) recommendation for pre-school and school-age children (58 g/kg crude protein) were CC (41%), CSC1 (83%), CSC2 (57%), CSC3 (62%), CSC4 (67%), CWC (31%), WC (28%),

Table 4: Amino acid composition (g kg^{-1} crude protein) of the various cracker formulations[1]

Amino Acids	Cracker[1]												
	CC	CSC1	CSC2	CSC3	CSC4	CWC	WC	CBWC1	CBWC2	CBSWC1	CBSWC2	CBSWC3	CSWC	FAO2
Asp	42	90	60	66	72	33	31	43	50	54	55	48	60	
Glu	111	148	128	129	134	218	246	151	45	158	140	170	168	
Ser	18	4	27	30	28	33	36	26	28	31	28	30	34	
Gly	15	33	22	24	26	23	26	20	21	24	22	23	26	
His	11	20	14	15	16	15	16	13	15	16	14	15	16	19
Arg	74	65	70	69	68	38	29	58	55	55	63	52	57	
Thr	15	31	21	23	25	19	20	18	20	22	21	21	24	34
Ala	20	35	26	28	29	23	23	22	24	26	25	24	28	
Pro	18	42	27	30	33	71	85	39	38	44	34	49	48	
Tyr	9	26	16	18	20	19	22	14	15	18	16	18	21	
Val	19	36	25	28	30	27	24	24	26	28	26	27	30	35
Ile	15	34	22	24	27	23	25	19	22	24	22	23	26	28
Leu	21	57	35	39	44	44	50	33	38	42	36	41	46	66
Trp	10	12	11	11	11	9	9	10	10	10	10	10	10	11
Lys	24	48	33	36	39	18	16	24	28	30	30	26	32	58
Phe	14	38	23	26	28	32	37	23	26	29	24	28	31	
SAA3	21	23	22	22	23	27	28	23	22	23	23	24	24	25
AAA4	23	63	28	43	48	52	59	38	41	47	40	46	51	63
AAS5	32	83	52	59	66	56	28	41	49	52	52	45	55	≥65
LAA6	Leu	Lys	Leu	Leu	Leu	Thr	Lys	Lys	Lys	Lys	Lys	Lys	Lys	

1 CC = plain cassava cracker, CSC = cassava-soybean cracker, CWC = cassava-wheat cracker, WC = plain wheat cracker; CBWC = cassava-bean-wheat cracker; CBSWC = cassava-bean-soybean-what cracker; CSWC = cassava-soybean-wheat cracker. 2 FAO/WHO/UNU (1985) essential amino acid reference pattern for pre-school/school age children. 3 SAA = sulfur containing amino acids – methionine + cysteine. 4 AAA = aromatic amino acids – phenylalanine + tyrosine. 5 AAS = amino acid scores = mg amino acids per g of cracker protein/mg of amino acid per g of reference protein for pre-school/school age children. 6 LAA = limiting amino acid.

CBWC1 (41%), CBWC2 (48%), CBSWC1 (52%), CBSWC2 (52%), CBSWC3 (45%) and CSBC (55%) while for the sulphur amino acids, the concentrations as a proportion of the FAO/WHO/UNU (1985) recommendation for pre-school and school-age children (25 g/kg crude protein) were CC (84%), CSC1 (92%), CSC2 (88%), CSC3 (88%), CSC4 (92%), CWC (108%), WC (112%), CBWC1 (92%), CBWC2 (88%), CBSWC1 (92%), CBSWC2 (92%), CBSWC3 (96%) and CSBC (96%).

The amino acid scores ranged from 32% in CC to 83% in CSC1 when the amino acid profile of children aged 2 – 5 years was used as reference. FAO/WHO/UNU (1985) recommended the use of the amino acid requirement pattern for the 2 – 5 year old child as the reference for foods meant for pre-school and school age children and even for adults. The CSC1, CSC4 had the highest amino acid scores that met the minimum score of 65% recommended by the FAO/WHO (1994) Codex Alimentarius for pre-school and school age children. Conversely, the lowest amino acid scores were observed in WC (28%), CC (32%), CBWC1 (41%), CBSWC3 (45%) and CBWC2 (49%). The amino acid score reflects the ability of the test protein to meet the protein needs of an individual and thus the ability to support optimal growth. A food product with low amino acid score has low ability to support optimal growth or rehabilitation. The most limiting amino acids were Lysine in WC, CBWC1, CBWC2, CBSWC1, CBSWC2, CBSWC3 and CSWC; Leucine in CC, CSC2, CSC3 and CSC4; and Threonine in CWC. These amino acid profiles indicated that, two composite products (CSC1 and CSC4) met the recommended amino acid score of 65%, however, the other products namely CSC2, CSC3, CWC, CBSWC1, CBSWC2 and CSWC contained amino acid patterns that were very similar (amino acid scores > 50%) to the reference pattern for pre-school and school age children for whom these crackers were designed. Lysine, sulphur amino acids, tryptophan and threonine are the most common limiting amino acids in plant-based foods (Milward, 1999; Young and Pellett, 1994). Example: Lysine, tryptophan and threonine are usually limiting in cereal grains such as maize, millet, sorghum and rice while sulphur amino acids are limiting in legumes e.g. beans, soybeans, cowpeas and pigeon peas. The combination of sorghum and/or cassava (with relatively good concentration of sulphur amino acids) with beans and/or soybeans (rich in lysine), help to increase the protein quality of the composite products through nutrient complementation. These results suggest that, despite low amino acid scores in some of the crackers, the products were still good sources of the essential amino acids and hence suitable as supplement for school-age children because they contained close to the recommended amino acid concentrations.

Table 5 presents the mineral content of the various crackers. Magnesium plays a role in bone mineralization, teeth maintenance, building up proteins, enzyme activities, normal muscular contractions, and transmission of nerve impulses. Magnesium concentration was highest in the CBSWC3 crackers (955.86 mg/100 g) but lowest in the CBWC2 crackers (316.64 mg/100 g). The concentration of Mg in plain cassava (CC), CSC1, CSC3, WC, CBSWC1 and CBSWC3 were similar ($p > 0.05$). The recommended daily intake of Mg for primary school children (6 – 13 years) is 110 – 200 mg with tolerable upper intake limit of 350 mg/day (FNB-IOM, 2003). All the composite crackers contained magnesium concentration levels above the recommended daily intake for primary school children. Mg deficiency is however uncommon and no harmful effects in humans with normal renal function have been reported due to excessive dietary intake of magnesium (Whitney *et al.*, 1990). Calcium concentrations ranged from 623.45-mg/100 g in CWC crackers to 415.22-mg/100 g in CBSWC2 cracker. According to the FNB-IOM (2003), the recommended daily intake of calcium for primary school children ranges from 800 to 1300 mg with tolerable upper intake limit of 2500 mg per day. The concentrations of calcium in the composite crackers formulated were 40 – 50% of the recommended daily intake levels for primary school children and none of the crackers contained calcium levels above the tolerable upper intake levels. Calcium is essential in children for building bones and teeth, functioning of muscles and nerves, blood clotting and for immune integrity (Whitney *et al.,* 1990).

For sodium, the concentration ranged from 324-g/100 g in the CSWC to 530-g/100 g in plain wheat crackers (WC). Sodium concentration of 1200 - 1500 mg has been recommended per day as adequate for primary school age children (6–13 years) (FNB-IOM, 2003). The tolerable upper intake limit is 1900 mg per day. The concentration of Sodium in the composite crackers was kept lower than the recommended daily intakes for primary school children. According to the Codex Alimentarius standards (FAO/WHO, 1994), supplementary foods that are designed for young children are required to maintain the concentrations of sodium and potassium as low as possible in order to avoid the problem of renal solute overload that leads to dehydration and exhaustion. Sodium is an essential electrolyte that helps to maintain the body's homeostatic and acid-base balances and assists in transmission of nerve impulses [30]. Potassium, just like sodium, is an electrolyte that plays a role in maintaining the homeostatic balance of the body fluids. Potassium concentrations in the composite crackers differed significantly ($p<0.05$) with the highest concentration of potassium in the plain cassava crackers (CC) (813.24 mg/100 g) and the lowest concentration (378.72 g/100 g) in the CSWC cracker (Table 5). The recommended daily intake of potassium for primary school children (6 – 13 years) is 3800 – 4500 mg. No tolerable upper intake levels of potassium that have been established for primary school children. In light of the recommended daily intake for primary school children, all composite crackers contained potassium concentrations that were within the acceptable levels.

Iron concentrations differed significantly ($p<0.05$) among the composite crackers. The concentration of iron in the crackers ranged from 8.1-mg/100 g in CSC1 cracker to 6.19-mg/100 g in CBSWC2 cracker. Crackers made from cassava-soybean flour blends had significantly higher ($p<0.05$) concentration of iron than those made from plain cassava (CC) flour. According to the FNB-IOM (2003), the recommended daily intake of iron for primary school children is 8 – 10 mg and the tolerable upper intake

Table 5: Mineral concentration (mg/100 g) of the composite crackers formulations[1,2]

Cracker[3]	Ca	Na	Mg	K	Cu	Zn	Mn	Fe
CC	489.15±12.14b	335.08±9.79e	361.58±10.70ab	813.24±14.79a	1.17±0.02a	2.24±0.08e	5.52±0.20a	6.63±0.09e
CSC1	597.33±26.95a	424.35±19.78bcd	399.52±14.55ab	526.01±12.26e	1.74±0.04a	4.08±0.69a	5.89±0.15a	8.10±0.00a
CSC2	446.62±12.37c	388.73±2.05cde	325.19±6.39b	646.34±46.46cd	1.31±0.60a	2.86±0.06bcde	3.40±0.56de	7.36±0.11cd
CSC3	623.47±33.92a	483.55±4.19ab	470.83±4.31ab	781.03±7.78ab	1.58±0.08a	3.76±0.07ab	4.33±0.80b	7.72±0.23bc
CSC4	527.49±9.85b	419.77±26.27bcd	341.16±23.89b	615.57±21.84d	1.50±0.10a	3.28±0.11abc	4.15±0.22bc	7.33±0.06d
CWC	434.18±29.97c	445.55±10.20bc	287.94±10.30b	194.59±4.11g	1.22±0.08a	2.30±0.22de	2.45±0.10f	6.68±0.12e
WC	517.31±4.29b	530.67±5.67a	356.76±5.13ab	105.72±6.45h	1.41±0.06a	3.76±0.06ab	2.82±0.18ef	6.25±0.07f
CBWC1	488.15±13.56b	379.65±14.88cde	350.62±10.52b	645.68±47.39cd	1.20±0.05a	3.52±0.19abc	3.36±0.13de	6.76±0.11e
CBWC2	446.56±4.46c	341.54±0.65e	308.95±0.25b	384.56±7.93f	1.19±0.00a	3.61±0.04ab	3.21±0.01de	6.73±0.01e
CBSWC1	503.96±7.18b	425.32±18.42bcd	376.75±8.42ab	716.36±15.55bc	1.25±0.05a	3.20±0.00abcd	3.33±0.07de	6.77±0.27e
CBSWC2	415.22±7.14c	370.23±28.20de	316.64±6.30b	718.96±11.87bc	1.32±0.65a	2.66±0.33cde	3.65±0.09bcd	6.19±0.10f
CBSWC3	441.03±12.28c	328.92±86.62e	955.86±901.26a	456.48±110.60ef	1.22±0.02a	2.28±0.13de	3.50±0.30cde	6.49±0.39ef
CSWC	445.21±10.36c	324.99±44.07e	313.12±7.88b	378.72±16.20f	1.16±0.17a	2.94±1.12bcde	3.11±0.11def	7.76±0.10ab

[1] Means ± SD based on tree analyses.
[2] Means within a column with different superscripts are significantly different at ($p<0.05$).
[3] CC = plain cassava cracker; CSC = cassava-soybean cracker; CWC = cassava-wheat cracker; WC = plain wheat cracker; CBWC = cassava-bean-wheat cracker; CBSWC = cassava-bean-soybean-wheat cracker; CSWC = cassava-soybean-wheat cracker

level per day is 40 mg. Consumption of 100 g of the composite crackers would provide 80 – 100% of the recommended daily intake for iron and would not exceed the tolerable upper intake level. Iron is an essential micronutrient that plays a key role in the biosynthesis of haemoglobin, myoglobin, and enzyme/co-enzymes. It enhances the body's immune system thus reducing infections (Whitney et al., 1990; Walker, 1990; King and Burgess, 1993). For both male and female school-age children, the need for iron increases with rapid growth and the expansion of blood volume and muscle mass (Russell, 2001). Literature suggests a causal link between iron deficiency anaemia and less than optimal learning behaviour among primary school children (Nokes *et al.,* 1998).

Table 5 data show the variations ($p<0.05$) in zinc concentrations among the composite crackers. The highest zinc concentration (4.08 mg/100 g) was observed in CSC1 crackers while the lowest concentration (2.24 mg/100 g) was observed in the plain cassava cracker (CC). The recommended daily intake of zinc for primary school children (6 – 13 years) is 5 – 8 mg with the tolerable upper intake levels of 12 – 23 mg per day (FNB-IOM, 2003). Consumption of 100 g of crackers would thus provide about 50 – 80% of the daily-recommended intake for zinc and would not exceed the tolerable upper intake levels. Zinc is an important micronutrient for young children since it is involved in the biosynthesis of more than 200 enzymes, growth hormones, hormone receptors, neuropeptides, proteins, and other genetic materials that promote optimal physical and mental growth (Fabris and Mocchegiani, 1995). Zinc also enhances the immune integrity (Walker, 1990; Hambridge, 1986). Studies among elementary and primary school children revealed that, hair zinc concentrations correlated strongly with reading ability, suggesting that zinc deficiency interfered with academic performance of the school children (Cavan *et al.*, 1993).

Concentration of copper in the composite crackers ranged from 1.16-mg/100 g in CSWC crackers to 1.74-mg/100 g in CSC1 crackers (Table 5). Copper concentrations did not differ significantly ($p > 0.05$) among the various composite crackers. This implied that, the blending of various proportions of cassava, soybean, bean and/or wheat flours used in the formulations did not affect the concentration of copper in the crackers. The recommended daily intake of copper for primary school children is 0.44 – 0.70 mg and the tolerable upper intake levels ranges from 3 to 5 mg per day (FNB-IOM, 2003). Based on these results, all composite crackers contained copper concentrations above the recommended daily intake of copper for primary school children (0.44 – 0.70 mg) but below the tolerable upper intake levels (3 - 5 mg). Copper is essential in the absorption and utilization of iron during haemoglobin and myoglobin synthesis and forms part of several enzymes (Winzerling and Law, 1997). Increased dietary intake of copper along with iron in the composite crackers may therefore have the beneficial effect of enhancing iron uptake and utilization.

Results on the sensory evaluation and acceptability of the various composite crackers are presented in Table 6. The appearance of the plain wheat crackers (WC) was the most appealing. Composite crackers whose appearance was similarly liked by the consumers were CWC, CSC4 and CSWC. The CSC2, CSWBC1, CSWBC2 and CWBC2 crackers had appearance that was least appealing. Extrusion cooking and blending of the cassava and wheat flours with soybean and bean flour altered the colour of the composite products significantly ($p<0.05$). The composite CSC1, CBWC1, CC, CBSWC1, CBSWC2, CBSWC3, CSC4 and CSWC crackers had the most appealing colour ($p<0.05$) to the consumers similar to that of the plain WC (control). In terms of smell, CSC4 and CSWC had the most appealing smell ($p<0.05$) similar to the plain WC (control), while CSC2, CBWC1, CC, CBSWC1 and CBSWC2 composites had a smell that was least appealing to the consumers. Smell and taste are important sensory quality attributes that constitute the flavour of a food product. Sensory quality attributes of food products are important because they influence consumer preference, selection and acceptability (Samuel *et al.*, 2006).

Regarding the taste, CSC4 and CSWC crackers displayed the most superior ($p<0.05$) taste similar to the plain WC (control), however, CWC, CSC3, CBWC1, CBWC2 and CBSWC3 crackers were also ranked high by the panellists. The CSWC cracker had the best texture (mouth feel) similar to the control (WC); however, the texture of CSC3, CSC4, CWC, CBWC1, CBWC2 and CBSWC3 was also ranked high by the panellists.

Regarding the overall acceptability, the order of preference for the various crackers was as follows: WC/CSC4/CSWC > CWC > CSC3/CBSWC1/CBSWC3/CBWC1/CSC1/CC/CBSWC1 > CBSWC3/CSC2. None of the crackers was ranked by the consumers as objectionable or unacceptable.

Blending of wheat and other flours with legumes and has been reported to reduce the consumer rating for various organoleptic attributes. In a study of supplementary foods for pre-school children, composite mixtures of maize with bean flour received low rating scores for colour, aroma and taste (Mosha and Mary, 2005). In another study involving the use of mung beans and cowpeas, consumer rating scores were significantly lower, but were improved considerably when flavours such as ginger, vanilla and chocolate were added to the composite mixtures (Marrero *et al.,* 1988). This suggests that, the organoleptic quality of the composite crackers could have been greatly improved if flavours would have been added. Likewise, inclusion of high fat and/or high protein legumes in the composite mixtures e.g. soybean flour, has been reported to improve the mouth feel.

Conclusion

This study elucidated the potential of using cassava flour in developing crackers for addressing the problem of under-nutrition among primary school children. It has opened new possibilities for utilizing the under-utilized cassava flour in Tanzania. Although plain cassava flour could produce good quality crackers, blends of cassava with soybean and bean flour have shown nutritional and sensory advantage. Cassava flour could substitute up to 70%

Table 6: Mean scores ratings for sensory attributes and overall acceptability of the composite crackers[1,2]

Cracker[3]	Appearance	Smell	Colour	Taste	Mouth feel	Overall acceptability
CC	3.50±1.11b	3.00±1.14cdef	3.35±1.27bc	2.70±1.28ef	2.82±1.13ef	2.62±1.00cd
CSC1	3.45±0.88b	3.17±1.22cde	3.00±1.22cd	2.90±1.08de	2.77±1.13ef	2.95±1.06c
CSC2	2.42±1.17d	2.52±1.18f	3.35±1.17bc	2.35±1.25f	2.50±1.19f	2.25±1.20d
CSC3	3.17±1.12b	3.22±1.01bcd	2.77±1.02d	3.22±0.93cd	3.22±1.01de	3.05±0.96c
CSC4	4.02±0.95a	3.72±0.76a	4.60±0.50a	4.70±0.46a	3.70±1.10bcd	4.52±0.55a
CWC	4.37±0.84a	3.27±1.39bc	3.10±1.24cd	4.00±0.99b	3.90±0.93bc	4.02±0.99b
WC	4.37±1.08a	4.35±0.74a	3.80±1.16b	4.85±0.36a	4.15±0.70ab	4.67±0.66a
CBWC1	3.12±1.34bc	2.85±1.14cdef	3.67±0.97b	3.02±1.31cde	3.20±1.09de	2.90±1.27c
CBWC2	2.65±1.38cd	3.10±1.15cde	3.70±1.15b	3.42±1.15c	3.45±1.20cd	3.05±1.26c
CBSWC1	2.40±1.24d	2.70±1.22def	3.37±1.05bc	2.82±1.13def	2.80±1.14ef	2.67±1.10cd
CBSWC2	2.37±1.07d	2.62±0.07ef	3.30±1.16bc	2.65±1.03ef	2.60±1.17f	2.35±0.98d
CBSWC3	2.97±1.25bc	3.07±1.12cde	3.40±1.26bc	3.30±1.27cd	3.37±1.26d	3.05±1.19c
CSWC	4.07±0.96a	4.32±0.78a	4.62±0.63a	4.42±0.93ab	4.47±0.78a	4.35±1.11ab

[1]Rating scores for sensory quality attributes; 5 = like very much; 4 = like moderately; 3 = neither like nor dislike; 2 = dislike moderately; 1 = dislike very much

[2]Rating scores in columns with different superscripts are significantly different at $p<0.05$.

[3] CC = plain cassava cracker; CSC = cassava-soybean cracker; CWC = cassava-wheat cracker; WC = plain wheat cracker; CBWC = cassava-bean-wheat cracker; CBSWC = cassava-bean-soybean-wheat cracker; CSWC = cassava-soybean-wheat cracker.

of wheat flour, which is used in conventional processing of crackers without adversely affecting the sensory quality of the product. At 50% cassava flour substitution, the protein, fat and energy contents became optimal for the nutritional and energy needs of primary school children when 100 g of the crackers are taken per day. Higher substitution of cassava flour above 50% reduced the protein, fat, and energy contents below acceptable levels. The sensory quality attributes of the crackers at all levels of cassava flour substitution were liked and accepted by the panellists.

The composite crackers contained Fe, Mg, Cu, Zn and Ca concentrations in the ranges that are recommended for primary school children. The concentrations of the essential minerals were highest in the CSC1 CSC3, CSC4 and CSWC crackers. Organoleptically, the CSWC cracker ranked highest in colour, smell and mouth feel while the CSC4 cracker was liked very much in terms of taste and appearance. Overall, CSC4 and CSWC crackers were the most accepted composite crackers similar to the control (WC) and none of the crackers were disliked by the consumers. The fortified cassava-bean-soybean composite crackers therefore have a potential for use as supplementary foods to increase protein, energy and micronutrients intake of primary school children in Tanzania. When used as a snack, these crackers may help to alleviate the short-term hunger at school thus increasing the attention span in class, comprehension and school attendance, reducing truancy and improving the nutritional status of the school children.

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