DEVELOPMENT, SENSORY QUALITY AND ACCEPTABILITY OF CASSAVA- BEAN/SOYBEAN COMPOSITE SUPPLEMENTARY CRAKERS FOR PRIMARY SCHOOL-AGE CHILDREN

BY

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ABSTRACT

The study was designed to formulate 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 flours, wheat and soybean flours on a replacement basis that included cassava-soybean crackers (CSC1, CSC2, CSC3 and CSC4), cassava-wheat (CWC) cracker, wheat cracker (WC), cassava- bean-wheat cracker (CBWC1 and CBWC2), cassava (CC), cassava-bean-soybean-wheat (CBSWC1, CBSWC2 and CBSWC3) and cassava-soybean-wheat (CSWC). Proximate and mineral compositions were determined for each product to assess the potential of the crackers to supply adequate amount of nutrients needed for growth and cognitive functioning. Physical properties and sensory qualities of the crackers were also assessed and compared with the plain wheat flour crackers (WC) simultaneously. Results showed no significant differences in spread ratio at $p<0.05$ among the crackers. Among the composites, the (CSC1, CSC3 and CSC4) cassava- soybean and (CSWC) cassava-soybean-wheat crackers had higher ($p<0.05$) protein, fat and energy densities. The amino acid scores ranged from 32% in CC to 83% in CSC1. Fe, Zn, Mg and Ca concentrations were also significantly higher ($p<0.05$) in the (CSC1, CSC3 and CSC4) cassava-soybean, and (CSWC) cassava-soybean-wheat crackers. However, all composites had adequate essential nutrients needed for cognitive function. Sensory evaluation indicated that, the CSC4 cassava-soybean cracker was preferred very much in terms of taste and appearance while the (CSWC) cassava-soybean-wheat cracker ranked the highest in colour, smell and mouth feel. Nevertheless, the (CSC4) cassava-soybean cracker was liked very much with respect to overall acceptability along with the plain wheat cracker

(WC) and none of the cracker was disliked. Based on the results, it may be concluded that various blends of cassava, soybean and bean flour can be used to produce supplementary crackers that are acceptable and of comparable composition and sensory qualities of wheat crackers.

DECLARATION

I, ASHA MECK SADICK, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has neither been submitted nor being concurrently submitted for a similar degree award in any other University.

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DEDICATION

This work is dedicated to my beloved parents Mr. and Mrs. Said Meck Sadick and for laying the foundation of my education and to all primary schoolchildren in the African continent who endure the pain of hunger and malnutrition while pursuing their education.

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LIST OF ABBREVIATIONS AND ACRONYMS

CRSP:	Collaborative Research Support Program
FAO:	Food and Agriculture Organization
HIV:	Human Immune Deficiency Virus
PANTIL:	Programme for Natural Resources Transformation for Increased Livelihood
SPSS:	Statistical Package for Social Science
SUA:	Sokoine University of Agriculture
UNICEF:	United Nations Children's Fund
USAID:	United States Agency for International Development
WHO:	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The success of the child survival programmes and the expansion of basic education coverage have resulted in a greater number of children reaching school age with a higher proportion enrolled in primary schools in the developing countries (World Bank, 2000). However, there is increasing evidence that, nutritional deprivation combined with the heavy burden of diseases among schoolchildren adversely affect the children's long term school performance and overall development (UNICEF, 2002). This has led to increased efforts focusing on interventions to address these deplorable predicaments plaguing schoolchildren.

Undernutrition is among the major constraints to both 'Education for All' and the Millennium Development Goals of achieving universal primary education. A large group of schoolchildren, perhaps over half, are underfed, and poorly nourished (WHO, 2002). Undernutrition associated with inadequate energy intakes is common in many developing countries and micronutrient deficiencies, such as deficiencies of iron, iodine and vitamin A are becoming a serious problem for schoolchildren. These nutritional problems affect schoolchildren's attendance, scholastic performance and concentration in class (UNICEF *et al.*, 2003). Thus, development and consumption of fortified inexpensive composite supplementary snacks at school can help to ameliorate the malnutrition problems among primary schoolchildren.

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 diminish their cognitive development either through physiological changes or by reducing their ability to participate in learning experiences (Partnership for Child Development, 2001). 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). It has, therefore, become pertinent to focus on potential crops such as cassava which are abundant, inexpensive and underutilised in Tanzania.

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 centers (Liddell and Rae, 2001). The situation is however, changing as new policies are being formulated to help ensure that programmes focus on improving the nutritional status and the educational outcomes of children, targeting the poor and disadvantaged children (Donald *et al.*, 2005). Thus, effective programmes for promoting good nutrition for school age children are essential for effective learning and performance. Efforts are therefore needed to eradicate undernutrition and promote the potential of schoolchildren to become productive adults.

1.2 Problem Statement and Justification

The majority of the schoolchildren in Tanzania perform poorly in schools and many dropout of school due to poor nutrition and health related problems. According to FAO (2007), 22% of school age children in Tanzania are stunted owing to "chronic inadequate intake of food (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). Yet, street vendor's snacks are nutritionally expedient due to unhygienic environment in which they are offered. 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 assertion has been used to draw the conclusions that, breakfast and mid-morning snacks influence the nutritional status and school performance of schoolchildren.

Cassava is one of the copious food crops that grows in most areas of Tanzania, but it is underutilized (Mlingi and Ndunguru, 2003). Although cassava generally lacks a variety of other nutrients essential for active and growing children, it has high energy density and affordable. It was envisaged that, formulating cassava-based snacks enriched with bean and/or soybean protein and fortified with micronutrients can provide a well balanced nutritious supplement for schoolchildren. It can also serve as

an effective supplement to address the widespread undernutrition problem among children in rural primary schools. This in turn can improve overall health among schoolchildren in the country. Mosha *et al.* (2000), Abrams *et al.* (2003) and Brown (2000) recommend fortification of staple foods, supplementation and modification of traditional diets as some of the effective strategies to combat micronutrients deficiencies among schoolchildren. According to Pollitt *et al.* (1996), this kind of intervention provides between 10 and 30% of daily nutritional requirements (RDA) for the target population, depending on the nutrient and the programme. For certain nutrients such as iron, 100% of RDA may be attained. Powell *et al.* (1989) found significant differences in weight and height gain among children having and not having breakfast. It is therefore expected that, the daily supply of nutrients from snacks will improve the nutritional status and wellbeing in the long run thus enhancing the cognitive functions and learning abilities.

Development of convenient supplementary snacks from locally available food crops can offer an immediate breakthrough in addressing undernutrition among primary schoolchildren in Tanzania. Making use of imported snacks/foods which are very expensive is not sustainable. Such foods can only be affordable by children from high income families, who are minority. Thus, this aim of the current study was to contribute to the ongoing efforts to address the problem of undernutrition among schoolchildren. It is envisaged that, the developed cassava-bean/soybean composite snacks will be useful in supplementing schoolchildren of important nutrients, protein and energy thus improving their school attendance, attention span in class and comprehension.

1.3 Objectives of the Study

1.3.1 General objective

The core goal of this study was to develop nutrient-dense fortified cassava-bean/soybean composite supplementary crackers for primary schoolchildren.

1.3.2 Specific objectives

i. To devise apt formulations for efficient graham crackers/biscuits.

ii. To assess the physical properties of the formulated crackers.

iii. To determine nutritional profile (proximate composition and mineral content).

iv. To determine sensory quality and acceptability of the composite crackers.

1.4 Hypotheses of the Study

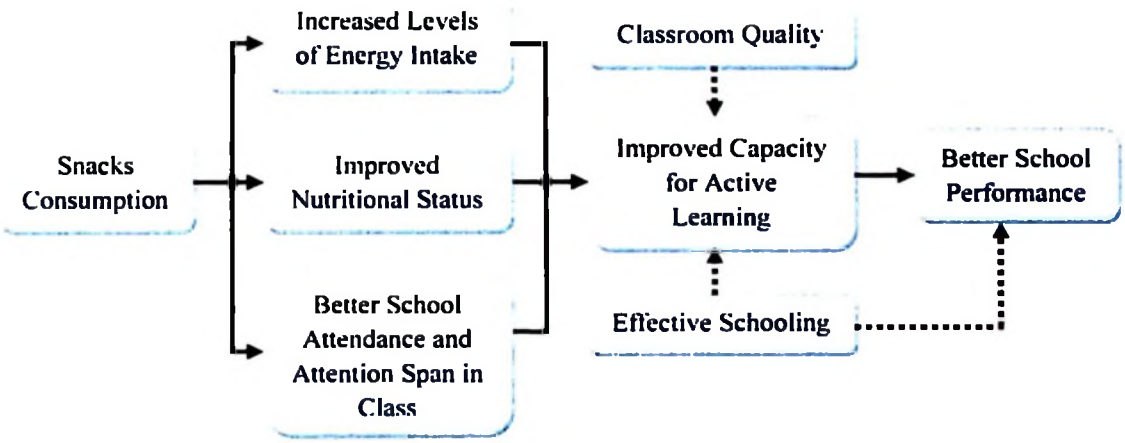
i. The physical-chemical properties of various cracker formulations do not have significant difference.

ii. The sensory quality of the various snack formulations do not differ significantly and are equally accepted by schoolchildren.

1.5 Conceptual Framework of the Study

To address the broad objective of the study and the research problem stated in the preceding section, a conceptual framework was developed as summarized in Figure 1. The conceptual framework draws from theoretical exposition of the impact of school supplementation programmes on energy availability, nutritional status, school attendance and performance.

According to the framework (Figure 1), most school supplementation programmes are designed to improve nutritional status, increase levels of energy, thus influence school attendance and attention span in classes. Researches on short-term effects of snack supplementation programmes on cognitive performance have often focused on micronutrients fortified energy-dense snacks with the aim of eliminating short-term hunger (Benton, 1998). Studies have shown that, children in the school supplementation programmes improved their average daily intake of energy, protein and iron by 15, 16 and 60 percent, respectively (Pollitt, 1996).



Source: Modified from Cueto (2001).

Figure 1: A conceptual framework of the study

Since providing breakfast has an impact on nutritional status in the long term, it would also have a positive impact on morbidity, and thus on school attendance (Fig 1). Families would send their children to school having confidence in the quality of food their children get at school. Many studies on school supplementation programmes in developing countries showed a positive effect of the programmes on

children's school attendance and dropout rates (Powell *et al.*, 1989 and Murphy *et al.*, 1998).

According to the framework, any single benefit in the aspects suggested could have a positive impact on children's school performance, but this hypothesis cannot always be confirmed (Cueto, 2001). It is not enough that children have a good nutritional status and attend school, but it is also necessary that the school provides adequate stimuli to learn (well-illuminated, aired rooms, enough space, adequate teaching etc.) in order to get the benefit from this basal condition.

Based on the above exposition, it is envisaged in the conceptual framework that: (i) snack consumption will have a short-term effect in improving selected learning skills, especially work memory. This effect will be more evident in children with previous history of malnutrition that may not be detected in other children; (ii) school snacks will have a positive effect on the nutritional status of children, manifested by increased weight and height gain in deprived populations (e.g. rural areas in Tanzania); (iii) school snack programmes will have a positive effect on school attendance and probably on dropout rates and (iv) the effect of snacks consumption on school performance will depend on the interaction between the programme, student characteristics (undernutrition) and school organisation. Unless the school setting guarantees a minimum quality standard, the benefits of school snacks consumption will not be evident in overall performance.

1.6 Outline of the Study

The dissertation is organised into five chapters. The second chapter presents the literature review of impacts of nutrition on cognition and school performance. The third chapter presents materials and methods used in this study including the product development process and chemical assays used, assessment of organoleptic attributes and acceptability and data handling techniques. The results and discussion of the major findings are presented in chapter four. Conclusions and recommendations drawn from the study are presented in chapter five.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

An understanding and awareness of the heavy burden of malnutrition among school children is growing. However, despite a better knowledge of the nutritional status of this age group, the extent of the burden of malnutrition is still not fully elucidated (ACC/SCN, 2002). Malnutrition in this age group can be addressed by developing relevant policies and programmes (ACC/SCN, 2005). The main nutritional problems facing the school-age child include stunting, underweight, iron deficiency anaemia and iodine deficiency disorders and vitamin A deficiency. Children can however exhibit catch-up growth if their environment improves. School-based interventions such as school feeding programmes can help to alleviate hunger and improve the nutritional status of school children if well planned (ACC/SCN, 2000).

2.2 Vulnerability of Schoolchildren

School children may be at increased risk of nutrient deficiencies owing to increased energy expenditure combined with decreased meal frequency, reduced maternal attention, and parasitic infections. The severity of parasitic infections such as hookworm and schistosoma is highest in this age group. Opportunities to target nutrient programmes at school-age children have increased as developing countries move towards providing universal primary education. School feeding programmes can contribute to preventing micronutrient malnutrition among children. School gardens can provide micronutrient-rich foods. Improving the nutrient status of

children will improve the cost effectiveness of investments in education. In most poor regions, a modest investment in the nutrition and health of school children would increase children's ability to learn more than it would for a comparable investment in teacher training, textbooks or improvement to school facilities (WHO/FAO, 2003).

2.3 Nutritional Status of Schoolchildren

At least 400 million children of school age are chronically infected with intestinal worms mainly roundworms, hookworms, and whipworms. Infection leads to malnutrition, iron-deficiency anaemia, stunted growth, and increased vulnerability to other infections. It has a serious impact on children's cognitive development - affecting concentration and work capacity and increasing absenteeism from school (WHO, 2006). In countries experiencing 'nutritional transition', overweight and obesity are increasing problems in the school-age children.

Other health problems facing school-age children are malaria, helminth infections diarrhoeal diseases, respiratory tract infections, and the direct and indirect effects of HIV/AIDS. Much of the disease burden is derived from the poor environmental conditions in which children live including exposure to biological, chemical and physical contaminants in the environment and a lack of resources essential for human health (UNICEF, 2002). Children with nutritional deficiencies are especially vulnerable to changes in metabolism that impact upon cognitive ability and performance of the brain. Evidence has shown that, prevention with nutritional supplements can improve performance, though among well-nourished children the impact is less pronounced (Bellisle, 2004).

2.4 Undernutrition among Schoolchildren

Stunting is widely believed to occur in early childhood (mostly by three years of age), and through a cumulative process. Children stunted at school-age are likely to have been exposed to poor nutrition since early childhood. The degree of stunting tends to increase throughout the school-age years. However, children can exhibit catchup growth if their environment improves (Frongillo, 1999). This suggests that, interventions in school-age children can supplement efforts in the preschool years to reduce levels of stunting and related side effects on children's health and education.

Underweight among school-age children, such as stunting, can reflect a broad range of insults such as prenatal undernutrition, deficiencies of macro- and micro-nutrients, infection and possibly inadequate attention by care givers. Wasting, which reflects acute malnutrition, is not as common as either stunting or underweight in school-age children. Nevertheless, wasting rates can change rapidly in situations of acute food crisis, with school-age children, adolescents in particular, becoming severely malnourished in such situations (Grantham and Ani, 2001).

One of the largest studies of anthropometric status of rural school children in low income countries (Ghana, Tanzania, Indonesia, Vietnam and India) found the overall prevalence of stunting and underweight to be high in all five countries, ranging from 48 to 56% for stunting and from 34 to 62% for underweight. In all countries surveyed, there was a trend for height-for-age and weight-for-age z-scores to decrease with age, implying that as children grew older, they became progressively shorter relative to their peers in the reference population. In all the countries, boys

tended to be more stunted than girls and in all countries, boys were more underweight than girls (Partnership for Child Development, 1998).

Studies have found out that, severe stunting in the first two years of life is strongly associated with lower test scores in school-age children (age 8 - 11). However, deficits in children's scores were smaller at older ages, suggesting that adverse effects may decline over time. In addition, lower test scores were related to late enrollment, increased absenteeism and repetition of school years among stunted children. These findings indicate that, stunted and non-stunted children can benefit similarly from education (Mendez and Adair, 1999). Also, short stature has been associated with late enrollment for primary school children in Ghana and Tanzania (Partnership for Child Development, 1999).

Few representative data are available on the levels of malnutrition in schoolchildren. Recent studies on schoolchildren in Tanzania have shed new information on stunting, wasting and underweight. One of the largest study on anthropometric status of rural school children by the Partnership for Child Development (1998) revealed that, prevalence of stunting and underweight in the country, ranged from 48 to 56% for stunting and from 34 to 62% for underweight. Another longitudinal study by Stoltzfus (1997) focusing on the changes in height and weight of schoolchildren in Pemba Island, Zanzibar showed that, stunting increased with age (14% in seven year olds increasing to 83% in 13 year olds) and peaked in girls at age 12; then declined when they entered their pubertal growth spurt. In boys, however, the prevalence of stunting rose steadily up to age 13 years and thereafter declined slowly.

2.5 Child Nutritional Status and School Performance

Nutritional status is a powerful determinant of numerous health, developmental and educational outcomes among youths. In addition to affecting physical growth and maturation, it influences a young person's attention span, learning capacity and ability to fully engage in educational experiences (Pollitt, 1990; Del-Rosso and Marek, 1996; Levinger, 1996). Research from around the world has shown that, undernourishment in early childhood has the potential to negatively influence school aptitudes, time of school enrollment, school attendance and concentration (Pollitt, 1990; Levinger, 1996; WHO, 1996). Since poor nutrition interferes with the educational mission of schools, and since schools reach the vast majority of young people, they represent an ideal venue for nutrition intervention programmes and services. Furthermore, the dietary, hygienic and exercise habits that affect nutritional status are formed, and are thus susceptible to modification, during the school age years (WHO, 1998).

Diet has an impact on children's ability to think in the short- and long-term. A recent review of research on the effects of deficiencies in zinc, iodine, iron and folate on the cognitive development of school-aged children highlighted the significance of nutrition in the post-infancy period. For example, deficiencies in iron and zinc have been associated with impairment of neuropsychological function, retardation of growth and development, reduced immunity and increased vulnerability to infectious diseases (Sandstead, 2000). Tests on animals suggest that, zinc deficiency reduces the ability to concentrate and memorise. During periods of rapid growth, as in early

life, zinc deficiency has been associated with increased emotional responses to stress and impaired motor activity (Bryan *et al.*, 2004).

Protein-energy malnutrition refers to the combination of nutritional deficiencies and infections. Iron deficiency indicates a depletion of stores of iron in the body. Both are developmental risk factors that are prevalent among low-income children in developing countries. Malnutrition in early life impacts upon cognitive and behavioural development. Experiments on the ability of nutrition interventions to improve the performance of stunted or malnourished children on mental and motor development tests have been successful. After allowing for socio-economic and schooling factors, young undernourished children benefited from nutritional supplements, more so than healthier children from higher socio-economic backgrounds (Pollitt and Gorman, 1994).

The supply of glucose to the brain impacts upon memory and mood. Benton (2001) suggests that, when engaging in cognitively demanding tasks, such as schoolwork, repeated supplies of glucose to the brain enhances cognitive functioning and improves memory and mood. In 2004, Bellisle published a review on the effects of diet on behaviour and cognition in children. The paper drew together a wealth of research on the short- and long-term effects of nutritional composition and meal pattern on children. Research on the immediate effects of glucose on cognition demonstrated that, the brain appears to be sensitive to short-term fluctuations in glucose supply. Research on the impact of fasting on cognition, in which both well- and undernourished 9 to 11 year old children (n = 71) were tested for the effects on memory and attention, it was revealed that, an overnight and morning fast among

schoolchildren had deleterious effects on memory and attention (Pollitt *et al.*, 1998; Pollitt and Gorman, 1994).

2.6 Micronutrients Deficiencies among Schoolchildren

Deficiencies of iron and iodine are among the most harmful types of nutrient deficiencies with regard to cognition. Iron deficiency renders children listless, inattentive and uninterested in learning. Literature suggests a causal link between iron deficiency anemia and less than optimal behavior for learning. Poor performance on a wide range of achievement tests among iron deficient children in school has been consistently documented. Nutritional disorders, particularly deficiencies of iron, iodine, and vitamin A are major problems for school-age children in low income countries. It has been shown that, such deficiencies can negatively impact on growth, increase susceptibility to infections and also impair the mental development and learning ability of school children (Nokes *et al.*, 1998).

2.6.1 Iron deficiency anemia

Iron deficiency is the most common nutritional disorder in the world and is estimated to affect more than 2 billion people of whom 1.2 billion suffer from iron deficiency anemia (Gillespie, 1998). Insufficient intake of iron rich foods is the major cause of iron deficiency. It can also be caused by parasitic infections (particularly hookworm and malaria) and deficiencies of other nutrients (Hall *et al.*, 2001). There is little evidence to suggest any recent decrease in the prevalence of anemia. It is estimated that, 53% or 210 million school-age children suffer from iron deficiency anemia. The

highest prevalence is reported in Asia (58.4%) followed by Africa (49.8%) (WHO, 2000).

Prevalence of IDA among school-age children

In a survey of nearly 14,000 rural school children in Africa and Asia, the prevalence of iron deficiency was more than 40% (WHO, 2000) in five African countries (Mali, Tanzania, Mozambique, Ghana, and Malawi) amongst children aged 7 - 11 years and in four African countries (Mali, Tanzania, Mozambique and Malawi) amongst children aged 12 - 14 years. In the two Asian countries studied, the overall prevalence of iron deficiency was considerably lower than in Africa (around 12% in Vietnam and 28% in Indonesia among 7 - 11 year olds). Children aged 7 - 11 years were found to have lower mean hemoglobin concentrations, while iron deficiency was found to be more common in the older age group. Girls were found to have lower hemoglobin concentrations than boys, although the overall prevalence of iron deficiency was higher in boys, particularly in the 12 - 13 year age group. An association between late enrollment in school, as compared to enrolling closer to the correct age, and a higher prevalence of anemia was also found (Partnership for Child Development, 2001).

2.6.2 Iodine deficiency and iodine deficiency disorders

Iodine deficiency affects an estimated 1.6 billion people worldwide and an estimated 60 million school-age children. The consequences of iodine deficiency include, severe mental retardation, goitre (a condition involving the enlargement of the thyroid gland and a disruption of normal thyroid production), hypothyroidism,

abortion, stillbirths, and low birthweight and mild forms of motor and cognitive deficits (Van den Briel, 2000). Iodine deficiency is the leading cause of preventable intellectual impairment worldwide. A number of studies comparing children living in iodine-deficient areas with those living in iodine sufficient areas have found out that, iodine deficient children have poorer levels of cognitive development and school achievement (Grantham, 2000).

2.6.3 Zinc deficiency

In observational studies among elementary school-age children, hair zinc was related to reading ability, suggesting that zinc deficiency interfered with academic performance (Cavan *et al.*, 1993). Three randomized trials of zinc supplementation measuring cognitive development among school-age children have been reported. A trial in Canada found no differences when children were tested with subscales from the Detroit Test of Learning Abilities (Gibson *et al.*, 1989). Trials in Chinese children and Mexican-American children have shown that zinc-supplemented children demonstrated superior neuropsychological performance, particularly in reasoning, when compared with controls (Penland *et al.*, 1997). These trials suggested that, the beneficial impact of zinc supplementation may have an impact on specific neuropsychological processes that are evident in time-dependent challenging tasks, namely attention and reasoning, rather than in general performance tasks (Sanstead *et al.*, 1998). More research is needed to replicate existing studies and to clarify the timing and duration of the relationship between zinc status, neuropsychological functioning and academic performance.

2.7 Short-term Hunger among School-age Children

Children who experience hunger or have poor dietary intakes tend to have poorer school performance including late enrolment, and poor attendance, behavior, cognition and achievement levels. Thus they are more likely to drop out of school early and to repeat classes. There is less information on their psychosocial function. Such children also come from the poorest families and are more likely to have frequent or chronic infections. The challenge is to determine whether and to what extent these relationships are causal and whether providing appropriate nutritional and health interventions at school age will improve the children's performance. In addition, there is an emerging problem of orphans in sub-Saharan Africa. These children are less likely to enroll and attend school regularly. Many are exposed to hunger and are depressed (USAID, 2000).

Among other stressors, hunger and school attendance independently predict their depression. There is thus an urgent need for nutrition interventions. There is increasing evidence of the negative consequences for children suffering from short term hunger, especially for children who got to school without eating. Children who are hungry are more likely to experience difficulties in concentrating and performing complex tasks, even if they are well nourished (Del Rosso and Marek, 1996).

2.8 Role of School Feeding Programmes on Cognitive Performance

Various authors (Table 1) have shown that, by providing children with a nutritious breakfast at school, it is possible to improve children's general health and behavior, as well as school attendance and overall school performance.

Table 1: Studies showing effect of nutrition interventions on cognitive performance

Study	Study population	Intervention	Results
Benton and Roberts (1988)	90 Welsh school children 12 – 13 years	Vitamin/mineral supplement for 8 months (30 children); placebo (30 children); no treatment (30 children)	Significant increase in nonverbal intelligence in supplemented group
Schoenthaler *et al.* (1991)	615 US American school children	Vitamin/mineral supplements with 50, 100 or 200% RDA for 13 weeks compared with placebo	Major improvement in nonverbal intelligence by children on 100% RDA supplements
Sandstead *et al.* (1998)	740 Chinese school children 6 – 9 years from urban, low-income families	Supplements with 20 mg zinc, micronutrients or both, 6 days per week for 10 weeks	Micronutrient supplementation + zinc improved significantly neuropsychological performance and growth
Richter *et al.* (1997)	55 undernourished rural South African children 7 – 14 years; 53 well nourished controls 7 – 10 years	Test children received a school breakfast of fortified cereals with milk and banana for 6 months	The breakfast had a significant beneficial effect on cognitive and behavioural performance
Powell *et al.* (1998)	407 undernourished and 407 well nourished Jamaican school children	Breakfast every school day for 1 year (test group); one-quarter orange and same attention (controls)	Breakfast improved nutritional status, school attendance and achievement
Jacoby and López de Romaña (1998)	500 000 school children of Peruvian Andes 5 – 10 years	School breakfast with 60% RDA of vitamins and minerals, and 100% iron daily for 6 months	Anemia prevalence fell from 66% to 14%; school attendance improved significantly; improvement in vocabulary test.
Van Stuijvenberg *et al.* (1999)	115 South African children 6 – 11 years (test group); 113 controls	Cookies with 60% RDA beta-carotene, iodine and iron, and a drink with 90 mg vitamin C on school days for 1 year (test group); placebo snack (controls)	Significant improvement in short-term memory and attention in test group; also fewer illness-related absences from school

2.9 Nutrient Needs of School Age Children

The following are some of the essential nutrients needed for optimal growth and development of children.

2.9.1 Carbohydrate

Children 4 - 18 years require 45 to 65 percent of daily energy intake from carbohydrate. A minimum 130 grams of carbohydrate is recommended per day to provide sufficient glucose for the brain. A child who consumes approximately 2000 kcal per day would consume 225 to 325 grams of carbohydrate (based on 45 to 65% of energy) (National Academy of Sciences, 2000). Children can easily satisfy their carbohydrate needs by consuming at least 5 servings of grain products, 5 servings of fruit and vegetables and 2 - 4 servings of milk products. For example, the following foods provide 235 grams of carbohydrate: 2 slices whole wheat bread (26 g), 250 mL/1 cup macaroni (42 g), 250 mL/1 cup rice cereal (29 g), apple (21 g), banana (27 g), carrot (8 g), 125 mL/1/2 cup broccoli (5 g), 125 mL/1/2 cup corn (22 g), 750 mL/ 3 cups milk (36 g), 175 g yogurt (19 g). Examples of foods rich in carbohydrates include; maize, millet, sorghum, sweet potatoes and cassava (Virtual Medical Centre, 2007).

2.9.2 Fat

Children 4 to 18 years require 25 to 35 percent of daily energy intake from fat. A child who consumes approximately 2000 kcal per day should aim for a fat intake of 56 to 78 grams (based on 25 - 35% of energy). Saturated fat and trans fat are

associated with increased heart disease risk and therefore it is recommended that these fats be minimized in the diet. Fat consumed should consist predominantly of monounsaturated and polyunsaturated fatty acids. Children can easily exceed their fat requirements by consuming a lot of high fat low nutrient foods. Furthermore, the food choices for children lead to intake of high amount of saturated and trans-fatty aicds. For example, 3 chocolate chip cookies (48 g serving - 15 g fat), 1 chocolate bar (53 g serving - 15 g fat), 20 potato chips (40 g serving - 14 g fat), and 20 french fries, deep fried (100 g serving - 10 g fat). This adds up to 54 grams of fat and does not include foods eaten at other meals or snacks (National Academy of Sciences, 2000).

2.9.3 Protein

Protein requirements decrease gradually as peak growth declines. Boys and girls 4 - 8 years of age require about 19 g of protein per day. Children age 9 - 13 years of age require about 34 g of protein per day. The protein needs of children can easily be satisfied by choosing foods from each of the four food groups, particularly the milk and products and meat and meat products. For example, a child who eats 1 egg (6 g protein), 1/2 chicken breast (16 g protein), 250 mL/1 cup 2% milk (9 g protein), and 125 mL/ 1/2 cup of cooked frozen peas and carrots (3 g protein) would consume 34 g of protein and satisfy his/her daily requirements (National Academy of Sciences, 2000).

2.9.4 Fibre

Children may have trouble getting the recommended amount of fibre in their diet due to low intakes of vegetables, fruit, whole grains, beans and legumes (American Dietetic Association, 2004). The daily recommendation is 25 grams of fibre per day for children aged 4 - 8 years. Girls aged 9 - 13 should aim at 26 grams per day and boys of the same age should take 31 grams of fibre per day (National Academy of Sciences, 2000). To get this amount of fibre children need to consume the minimum number of servings from the grain products (5 servings) and vegetables and fruit (5 servings) groups. Whole grains such as whole wheat breads and cereals have more fibre than fruits and vegetables with their peels. Fruit juice is not a good source of fibre. Beans and legumes, nuts and seeds also provide good amount of fibre.

2.9.5 Vitamins and minerals

Table 2 summarizes the recommended daily nutrient intakes for school-age children.

Table 2: Recommended daily intakes (RDI) of various nutrients for school age children

Nutrient	4-6 yrs	7-10 yrs	11-14 yrs	15-18 yrs
Iron (mg)	6.1	8.7	14.8	14.8
Zinc (mg)	6.5	7	9	7
Calcium (mg)	450	550	800	800
Vitamin A (μg)	500	500	600	600
Vitamin C (mg)	30	30	35	40
Folate (μg)	100	150	200	200
Sodium[1] (mg)	1177	1961	2353	2353

[1]Scientific Advisory Committee on Nutrition (SACN)

Source: Crawley (2005)

Children should consume a diet that provides essential nutrients in amounts sufficient to meet the Recommended Dietary Allowance (RDA) or Adequate Intake (AI) while not exceeding the tolerable upper intake levels (UL) specified by the Dietary Reference Intakes (DRI) (National Academy of Sciences, 2000.

2.9.6 Water

Water is an important beverage for students. Children need to be properly hydrated at all times. When children are involved in sports and due to hot weather, they have even higher needs for water. Water is preferred over fruit and soft drinks as these latter beverages are typically high in sugars, additives and sometimes caffeine. Sports drinks are not necessary unless a child is involved in strenuous exercise. It is recommended that, active children should drink 150 - 200 ml of fluid, 45 minutes prior to exercise, plus an additional 75-100 ml every 20 minutes during exercise. Water is recommended as the best choice of fluids (Virtual Medical Centre, 2007).

2.10 Nutritional Contribution of Cassava to the Diet

The composition of cassava root is shown in Table 3. Cassava roots are a rich source of carbohydrates. Most of the carbohydrates is present as starch (31% of fresh weight), with smaller amounts of free sugars (less than 1% of fresh weight). Cassava roots are low in protein (0.53 g/100 g dry matter), although higher concentrations of 1.5% have been reported (Ekpenyong, 1984). Protein from other sources is therefore needed if cassava is to be part of a balanced diet. Leaves have higher protein content.

Table 3: Nutrient composition of cassava

Component	Roots	Leaves
Moisture (g)	62.80	74.80
Energy (kJ/100 g)	580	-
Protein (g/100 g)	0.53	5.10
Starch (g/100 g)	31.00	-
Sugar (g/100 g)	0.83	-
Dietary fibre (g/100 g)	1.40	-
Ash (g/100 g)	0.84	2.70
Ca (mg/100 g)	20.00	350
P (mg/100 g)	46.00	56.00
Mg (mg/100 g)	30.00	-
K (mg/100 g)	302.00	-
S (mg/100 g)	6.40	-
Fe (mg/100 g)	0.23	218.00

Source: Holloway (1988).

2.11 Extrusion Cooking

Extrusion processing is used globally for the production, modification, and improvement of quality of various food products such as ready-to-eat cereals, snacks, pet foods and aqua feeds (Harper, 1981; Colonna *et al.*, 1989; Frame, 1994). Extrusion is a high temperature short time process that is widely used for processing of different food products (Harper, 1981; Frame, 1994; Smith and Singh, 1996). A very small variation in processing conditions can affect the product quality (Desrumaux *et al.*, 1999). During extrusion cooking, the ingredients mixture undergoes numerous structural and chemical transformations, such as protein denaturation, starch gelatinization, degradation reactions of vitamins, pigments,

maillard browning and complex reactions between amylose and lipids (Ilo and Berghofer, 1999).

Starch is a major functional ingredient that is responsible for the expansion of the extruded products. In extrusion industry, starch ingredients are used to produce puffed products (Kokini *et al.*, 1992). During the process of extrusion, starch gets plasticized with water and is subjected to a specific mechanical and thermal energy treatment. Many studies have shown that, starch plays a major role in expansion, while the other ingredients namely proteins, fats and fiber act as diluents (Horn and Bronikowski, 1979). For better expansion, the minimum starch content was found to be 60 to 70% (Conway, 1971). The expansion of starch depends on its degree of gelatinization. Temperature and moisture content are the two primary factors that influence the gelatinization and hence the expansion of starch (Mercier and Feillet., 1975; Chinnasamy and Hanna, 1988). The extent of macromolecular degradation is known to be a function of extrusion parameters namely temperature, moisture content and screw speed (Davidson *et al.*, 1984).

Heat treatment of food product inside an extruder results in gelatinization of starch, protein denaturation, and liquid modifications. It enhances the digestibility due to the inactivation of enzymes, microbes, and many anti-nutritional factors present in food materials. The material generally becomes plastic during the process of extrusion cooking and often expands or puffs when leaving the die as moisture in the material flashes as steam (Sheriff *et al.*, 2005). The expansion of the extrudates and its texture depends mainly on the interaction of shear, heat, and the moisture that is present in the extruder (Mercier, 1979; Owusu-Ansah *et al.*, 1984). Moisture has a great

influence on the extrudates' quality by affecting the cell structure and thus influencing the fragility of expanded products (Mercier, 1979; Kitabatake *et al.*, 1985; Miller, 1985). The quality of the extruded products is determined by the chemical and structural transformations in foods during extrusion cooking (Bhattacharya and Hanna, 1987; Cai and Diosady, 1993; Zheng and Wang, 1994).

CHAPTER THREE

3.0 MATERIALS AND METHODS

This chapter presents the materials and methods employed in the development of the cassava-bean/soybean snacks. The chapter is divided into two major sections. The first section elucidates on the materials used and their sources, and the second section illustrates the methods and procedures used in material preparation, snack processing, the chemical assays and sensory evaluation carried out.

3.1 Materials

3.1.1 Plant materials

The snack formulated in this study was prepared from following materials; cassava (*Manihot esculenta*), bean (*Phaseolus vulgaris*), wheat (*Triticum aestivum*) and soybean (*Glycine max*). Samples of sweet cassava roots were obtained from the PANTIL cassava project in the Eastern zone of Tanzania while beans were obtained from the Bean/Cowpea CRSP project at Sokoine University of Agriculture. Wheat and soybean flours were purchased from the retail shops in Morogoro town.

3.1.2 Additives

Additives used in the preparation of the snack included mineral and vitamin premixes, margarine, baking powder ($NaHCO_3$), iodised table salt and sugar. Mineral and vitamin premixes (Appendix 3) were purchased from Dyets Inc. (Bethlehem, PA., USA.) while all other additives were procured from a local supermarket in Morogoro town, Tanzania.

3.2 Methods

3.2.1 Processing of raw materials

3.2.1.1 Cassava processing

Fresh roots were received from the field soon after harvest and processing procedures were carried out immediately. Processing of the cassava roots into flour was done within a short time to minimize enzymic degradation processes. The subsequent processing operations involved five steps, i.e. peeling, washing soaking, chipping, drying and milling.

3.2.1.1.1 Peeling

The fresh cassava roots were cut longitudinally and transversely with a kitchen knife to a depth corresponding to the thickness of the peel (skin and cortex). The peel was then removed leaving the softer central part of the root. This traditional method of peeling is known to produce good quality cassava products.

3.2.1.1.2 Washing and soaking

Any dirt remaining on the surface of the peeled cassava root was washed off. The peeled and washed roots were then soaked for six hours in water to remove the mucilage and reduce cyanogens.

3.2.1.1.3 Chipping

After soaking, the peeled cassava roots were shredded into thin chips of approximately 0.2 - 0.5 cm width, 1 - 5 cm length and 0.1 - 0.4 cm thick using a chipping machine (Intermech Engineering, Morogoro). The chips were then pressed to reduce the water content. This in turn reduced the concentration of cyanogens and increased the drying rate.

3.2.1.1.4 Drying

The pressed chips were immediately sun-dried until a moisture content of less than 14% was attained. The sun-drying process took about 48 hours and was preferred to other methods of drying because it was simple, inexpensive and more efficient in degrading the cyanogens.

3.2.1.1.5 Milling

To obtain cassava flour, the dry chips were milled with a commercial hammer mill (Intermech Engineering, Morogoro). In order to maintain its quality, cassava flour was immediately packed in moisture proof polyethylene bags and stored in cool dry place until the time for use in snack production.

3.2.1.2 Beans processing

The beans were sorted and winnowed to remove extraneous materials, washed in cold water, sun dried for eight hours to a moisture content of less than 14%. The beans were thereafter ground to pass through a 0.8 mm screen.

3.2.2 Snack formulation

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) recommendations with some modification (Table 4). These included cassava cracker (CC), cassava-soybean cracker (CSC1), (CSC2), (CSC3), (CSC4), cassava-wheat cracker (CWC), wheat cracker (WC), cassava-bean-wheat cracker (CBWC1), (CBWC2), cassava-bean-soybean-wheat cracker (CBSWC1), (CBSWC2), (CBSWC3), cassava-soybean-wheat cracker (CSWC).

Table 4: Composition (g/100 g) of the crackers

Ingredients	Snack[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
Mineral 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 (iodized)	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	100.0	100.00	100.00	100.00	100.00	100.00

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

The crackers were formulated to provide the required amount of energy and micronutrients essential for supporting optimal growth in children and scholarly outcomes. They were optimized to improve the average daily intake of energy and specific micronutrients that are necessary for enhancing growth and cognition of schoolchildren. Most of the ingredients used were produced locally, inexpensive and were abundantly available in local markets.

3.2.3 Snack processing

Cassava and bean flours were extruded into precooked ready-to-feed flour that could be blended with other ingredients at varied proportions to produce composite crackers. Extrusion of the cassava and bean flour was carried out in a Twin Screw Extruder – Kneadel Model JS60D (Qitong Chemical Industry Equipment Co. Limited, YanTai, China) (Figure 2). The following extrusion conditions were adopted: Barrel temperatures were 130 °C (zone 1) and 157 °C (zone 2), main motor speed was set at 34.35 rpm and feeder speed at 12.30 rpm.

The extruded flour of cassava and beans was reconstituted into a supplementary graham cracker for primary schoolchildren on a par with FAO/WHO (1994) Codex Alimentarius recommendations for processing food for children. Thereafter mixed with other ingredients and fortified with mineral premixes as summarized in Table 4. Margarine was melted under mild heat and mixed with the dry ingredients maker (Model HUB-40; Precision North America Inc.). The ingredients were poured into a stainless steel mixing bowl of the dough mixer.

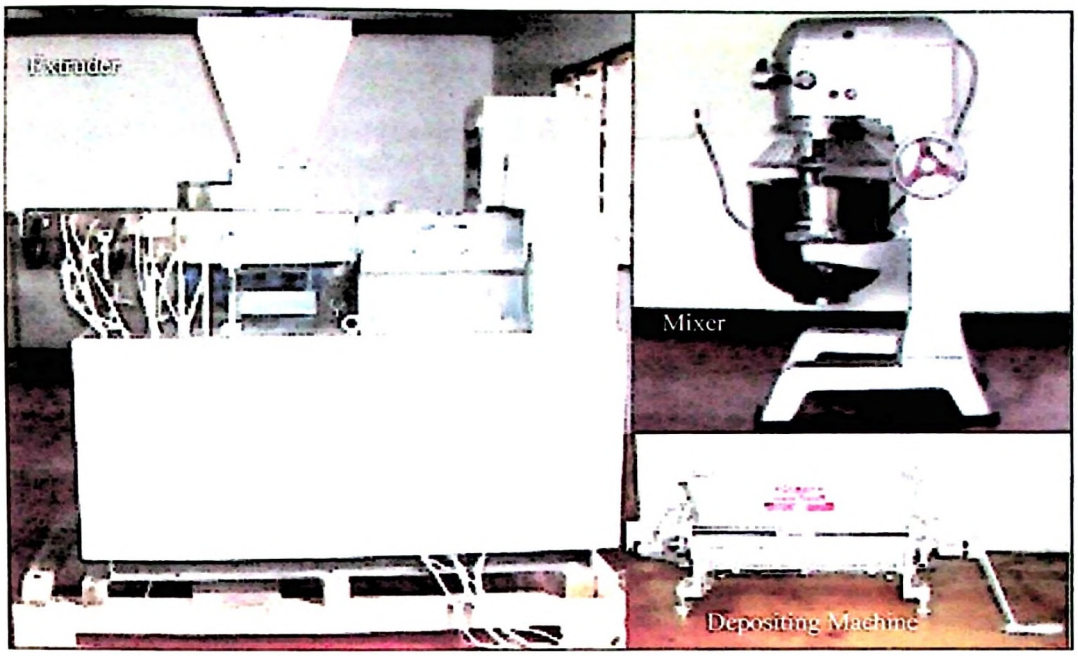


Figure 2: Machines used in snack processing

The dry ingredients were mixed with 500 ml of water per 100 kg of the mixture. The contents were kneaded well using a dough maker (Mode-HUB-40; Precision North America Inc.). The dough maker was set at speed no. 2 and each batch was kneaded for 10 min to obtain a stiff dough. The dough was then stamped out in round shapes of 6.0 cm diameter and 0.65 cm thickness, using a wire cut Kook-E-King Cookie depositing machine (Bench Model) (Figure 2). Dough pieces were placed in lightly greased trays, covered with aluminum foil and kept at room temperature for about 15 min. The dough pieces were placed in a pre-heated conventional oven set at 200°C and baked for 15 min until golden brown (Figure 3). The cooked crackers were thereafter removed from the oven, allowed to cool to room temperature and packaged in airtight polyethylene containers prior to sensory and chemical analyses.

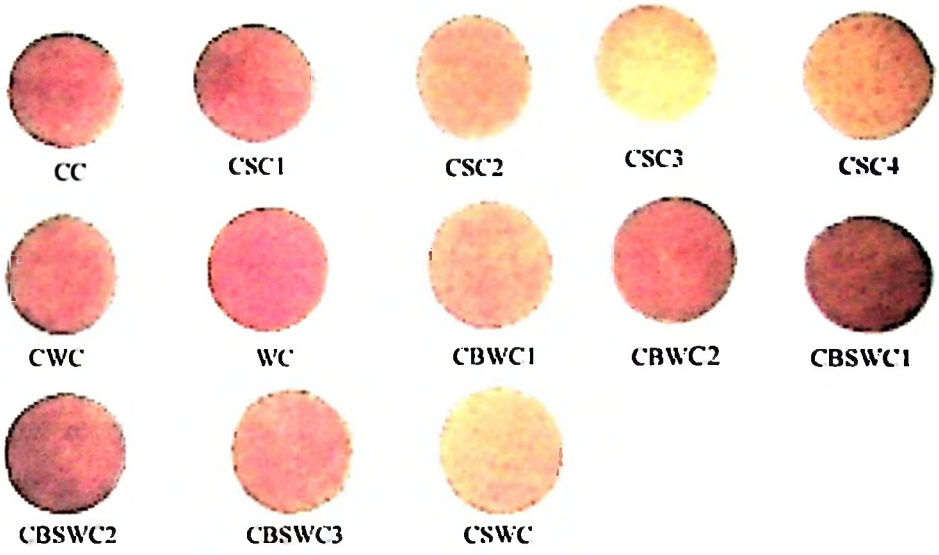


Figure 3: Samples of the cassava-based composite snacks

3.2.4 Physical analysis of the crackers

Physical parameters of the crackers namely diameter, thickness, weight and spread ratio were measured to determine the influence of various blend-formulations on the physical-chemical properties of the crackers. All physical measurements were taken according to the AACC (2000) procedures.

3.2.4.1 Cracker diameter

To determine the cracker diameter (D), six crackers were placed edge to edge. The total diameter of the six cookies was measured in cm by using a ruler. The cookies were rotated at an angle of 90° for triplicate readings. This process was repeated twice and the average diameter was reported in the nearest 0.1 cm.

3.2.4.2 Cracker thickness

To determine the thickness (T), six crackers were placed on top of one another. The total height was measured in cm using a ruler. This process was repeated thrice to get an average thickness value and recorded in the nearest 0.1 cm.

3.2.4.3 Cracker spread ratio

Spread ratio (SR) was determined from the diameter and thickness values using the equation:

$$SR = \frac{D}{T} \times CF$$

Where, SR = spread ratio

CF = correction factor at constant atmospheric pressure. Its value was 1.0 in this case.

D = Cracker diameter (cm)

T = Cracker thickness (cm)

3.2.4.4 Cracker weights

Weights in g were determined using OHAUS digital top loading balance (Model-CKW-55, OHAUS Corporation, Pine Brook, NJ USA). The weighing scale was calibrated at zero and three crackers were placed on the weighing scale at intervals and then the average reading was recorded the nearest 0.1 g.

3.2.5 Chemical analyses of the crackers

A composite sample of each cracker formulation was made by mixing three different crackers making approximately 5 g. The mixture was then poured into a mortal and

ground with a pestle to make a uniform mixture. Two grams of each sample were then measured into dry, pre-weighed Petri-dishes. Proximate and selected mineral composition of the different samples of crackers was analyzed according to AOAC (1995) procedures.

3.2.5.1 Moisture content

The moisture content of the crackers was determined in triplicate by oven drying method (AOAC, 1995). Petri-dishes containing the food samples were weighed, and dried in a conventional oven set at 105°C for 24 hours. After 24 hours, the dishes with dry samples were removed from the oven and placed in a decicator to cool. The dishes were thereafter weighed. The weight difference between the samples (before and after drying) was the moisture content, which was expressed as a percentage of the sample weight.

3.2.5.2 Protein content

The protein content of the crackers was determined by Kjeldahl method (AOAC, 1995; method 920.87). About 0.5 g portion of dried sample, in triplicate, were weighed onto a tared filter paper and quantitatively transferred into digestion tubes. Digestion was done at 420°C followed by distillation using Tecator Kjeltec system. Titration was done and nitrogen content calculated from the equation:

$$N = \frac{14.01 \times \left(titre\ (ml) - blank\ (ml) \times conc.of\ acid\ (N/Mol)\right)}{weight\ of\ dry\ sample\ (g) \times 10} \times 100$$

Where N = percent nitrogen

Percentage crude protein (%CP) was thereafter calculated from the percentage nitrogen using the conversion factor 6.25 (for plant materials):

$$\%CP = \%N \times 6.25$$

Amino acid content

The essential amino acid content of the composite crackers was computed by using the USDA National Nutrient Database for Standard Reference (www.nal.usda.gov/fnic/foodcomp). The amino acid scores were obtained by comparing the products' 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).

3.2.5.3 Fat content

The lipid content of the crackers was determined by Soxhlet Ether extraction method (AOAC, 1995; method 920.85). About 5.0 g portion of sample was weighed into a tared conical flask and the extraction unit was set onto the Soxhlet apparatus at 100°C. Lipid was extracted by using n-hexane for 10 hours. The extract was dried for 30 minutes at 100°C, cooled and then reweighed. Percentage fat was then calculated by using the formula:

$$\%Fat = \frac{(weight\ of\ flask + fat) - weight\ of\ dish)\ g \times 100}{weight\ of\ dry\ sample\ (g)}$$

3.2.5.4 Ash content

The ash content was determined by using AOAC (1995) official method 923.03. Four pre-cleaned crucibles were dried in oven, cooled in a desiccator and weighed. A sample ca 1.0 g was weighed onto each crucible, and placed in a muffle furnace pre-heated to 550°C. The samples were then ashed at 550°C for 24 hours. After ashing, the samples were removed from the furnace, placed in a desiccator to cool for 3 hours and thereafter weighed. Percentage ash was calculated from the equation:

$$\%Ash = \frac{weight\ of\ ash\ (g) \times 100}{weight\ of\ dry\ sample\ (g)}$$

3.2.5.5 Fibre content

Percentage fibre content of the crackers was determined by using AOAC (1995, method 920.86). One gram of the cracker sample was analysed using the 220 ANKOM Fibre-Tech set at 550°C for 2 hours. Fibre content was calculated and expressed in percentage using the equation:

$$\%Fibre = \frac{(C - B) - (E - D)}{A} \times 100$$

Where;

A = weight of dry sample (g)

B = bag weight (g)

C = bag + dry residue (g)

D = crucible weight (g)

E = crucible + ash (g)

3.2.5.6 Carbohydrate content

Carbohydrate content of the crackers was calculated as difference (AOAC, 1995) using the equation:

$$CHO = 100 - (CP + CFat + Ash + CFibre)$$

Where:

CHO = carbohydrate

CP = Crude protein

CFat = Crude fat

CFibre = Crude fibre

3.2.5.7 Energy content

Energy content of the crackers was determined according to AOAC (1995) procedure. Energy was obtained by multiplying the fat, protein and carbohydrate values by the Atwater factors of 9, 4 and 4, respectively.

$$Energy\ (kcal) = (CFat \times 9) + (CP \times 4) + (CHO \times 4)$$

3.2.5.8 Mineral content

The concentrations of Ca, Fe, Cu, Mg and Zn in the cracker samples were determined by using UNICAM Atomic Absorption Spectrophotometer (Model 919, Cambridge, U.K.). A single mineral hollow cathode lamp was used for each element. Standards were set at highest sensitivity on reading each corresponding lamp and wavelength. Zeroing was done after setting on flame and setting the wavelength (Ca: λ = 422 nm; Fe: λ = 248 nm; Cu: λ = 324 nm and Zn: λ = 213 nm). The mineral

contents were calculated and expressed in mg/100 g (DM) sample using the equation:

$$Mineral\ conc.(mg/100\ g) = \frac{GR}{1000\ ml} \times \frac{100\ ml}{SW} \times DF \times 100g$$

Where;

GR = Absorbance

SW = dry sample weight

DF = Dilution factor

3.2.6 Sensory evaluation of the crackers

Sensory evaluation was conducted to determine the consumers' response and for discerning the best cracker formulation. There were two panel groups. The first group comprised of 20 pupils from Sokoine University of Agriculture, while the second group comprised of 20 students from SUA Primary School. The crackers were placed in identical glass bowls coded in three digit numbers. Samples in glass bowls were presented to the panellists in a cool environment. Panellists were asked to test each product at a time, and express their degree of preference in relation to aroma, colour, taste, appearance and texture. After testing a product, the panellists were requested to rinse their palate before testing the next product. A 5-point Hedonic scale was used as a means of determining consumers' reaction to the sensory attributes, where five and one represented the highest and lowest order of preference, respectively (Appendix 1) (Larmond, 1977). A scale was also provided to indicate the degree of product acceptance ranging from highly acceptable to

unacceptable. To avoid fatigue, the panellists were allowed to test only seven products per day. The remaining samples were tested on a different day.

3.2.7 Statistical analysis

The data for proximate composition, amino acids and mineral concentrations and sensory quality of the various snack composites were subjected to one-way Analysis of Variance (ANOVA) using SAS (Statistical Analysis System) program (Version 8) for Windows®. A difference was considered to be significant at $p < 0.05$. Tests for differences between the means were done by Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

3.2.8 Ethical clearance

Approval to use human subjects was obtained from the Ethical Committee of the National Institute for Medical Research (Appendix 2). All panelists and the school head teachers (on behalf of the participating schoolchildren) signed a consent form to affirm their willingness to participate in the test panel. The panelists were free to decline participation or withdraw of the test panel at any stage without being persecuted.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

This chapter presents the results of the study. It is divided into three major sections. Section one highlights on the physical properties of the crackers, the second section delineates the nutritional profile of the snacks with focus on proximate composition, amino acids and minerals composition while the third section describes the sensory quality of the snacks and identifies the most acceptable crackers amongst the various formulations.

4.2 Physical Properties of the Crackers

Results in Table 5 show the physical properties of the various crackers. The data suggest that, the different levels of cassava, soybean and bean flours in the blends affected considerably the quality of the dough. The dough had the tensile strength and extensibility for sheeting, although they were non-gluten forming. Modest discrepancy was noted in the thickness and diameter of the plain cassava flour crackers (Table 5). The thickness of the plain wheat flour cracker (control) was 0.71 cm while that of plain cassava flour cracker was 0.82 cm, however, the thickness decreased significantly ($p < 0.05$) with the incorporation of soybean, wheat and bean flours. Cassava-soybean composites particularly those containing higher proportion of soybean flour, produced snappy rough surfaced and brown colour dough and cracker slivers. Extrusion might have favorably influenced the cohesiveness and colour of the cassava flour. Processing conditions during extrusion favour non-

enzymatic browning caused by Maillard reaction between proteins and reducing sugars (Berset, 1989).

Table 5: Physical properties of the crackers

Cracker[3]	Physical properties[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}	8.21±0.07^{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 two replications.

[2] Means within a column with different superscripts were significantly different at $p < 0.05$.

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

Spread ratios differed significantly ($p < 0.05$) among the cracker formulations. This implied that, all cracker formulations spread ratio suitable for further industrial processing such as sandwiching and packaging. Mechanical equipments for further processing do not normally tolerate variations in spread ratio. This finding was in

line with observation by Falomin and Lopez (1990) who reported that, spread ratio of cookies made with high protein flour did not develop during baking, as non-wheat high protein flours used in biscuits exhibit greater water retention than those made from wheat flour. The water in the system was insufficient to dissolve the sugar during baking which increased the viscosity of the dough therefore spread at a slower rate.

There were significant variations in the mean weights of the composite crackers ($p < 0.5$). The average weight for the plain cassava flour cracker was 17.49 g, however, the value decreased significantly ($p < 0.05$) with increasing levels of soybean and bean flour in the composites. This decrease in weight indicated that, the crackers containing soybean and bean flours lost more water upon baking. In general, cassava-bean-soybean flour composites compared flawlessly with the control (plain wheat flour cracker) in thickness, diameter, spread ratio and weight. 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. This implied that, the crackers had the required qualities to fetch market if they are commercialized.

4.3 Chemical Composition of the Crackers

4.3.1 Protein content of the crackers

The chemical compositions (g/100 g dry weight) of the various cracker formulations are summarized in Table 6. There was a significant difference in crude protein content among the different cracker formulations ($p < 0.05$). The protein content ranged from 3.35 g/100 g in CC to 31.54 g/100 g in CSC1.

Table 6: Proximate composition (g/100 g) and energy content (kcal/100 g) of the various cracker formulations[1,2]

Cracker[3]	Ash	Protein	Fat	Fiber	Carbohydrate	Energy (kcal)
CC	2.49±0.01^{e}	3.35±0.24^{h}	12.04±0.13^{h}	7.26±0.21^{ef}	74.86±0.16^{a}	421.17±1.50^{ef}
CSC1	3.87 ± 0.18^{a}	31.54±1.41^{a}	30.06±0.41^{a}	18.43±0.72^{a}	16.09±0.10^{k}	461.10±1.52^{a}
CSC2	3.25±0.14^{bcd}	12.15±0.48^{e}	19.79±0.46^{cd}	16.21±0.98^{ef}	48.59±1.14^{g}	421.12±6.76^{ef}
CSC3	3.71±0.02^{a}	16.88±0.09^{c}	20.83±1.11^{c}	16.95±0.23^{ef}	41.62±0.94^{i}	421.51±6.55^{ef}
CSC4	3.84±0.05^{a}	20.92±0.82^{b}	22.62±0.88^{b}	15.78±0.42^{cd}	36.82±0.32^{j}	434.59±5.88^{cd}
CWC	2.47±0.07^{e}	5.93±0.54^{g}	17.32±0.89^{f}	9.63±0.40^{bc}	64.65±0.02^{b}	438.19±5.76^{bc}
WC	2.32±0.05^{e}	6.33±0.86^{g}	18.98±0.48^{de}	9.56±0.75^{b}	62.81±0.41^{c}	447.42±0.79^{b}
CBWC1	3.08±0.02^{d}	9.64±0.36^{f}	16.82±0.51^{f}	8.97±1.03^{cd}	61.48±1.20^{d}	435.92±1.66^{cd}
CBWC2	3.11±0.01^{d}	11.77±0.49^{e}	15.29±0.19^{g}	9.19±0.17^{cdef}	60.64±0.15^{d}	427.27±0.29^{cdef}
CBSWC1	3.44±0.01^{bc}	15.10±0.21^{d}	19.87±0.86^{cd}	15.34±0.51^{def}	46.25±0.15^{h}	424.23±6.32^{def}
CBSWC2	3.48±0.01^{b}	14.47±0.56^{d}	17.92±0.44^{ef}	13.52±0.32^{ef}	50.61±0.34^{f}	421.61±3.06^{ef}
CBSWC3	2.32±0.01^{e}	13.04±0.79^{e}	15.01±1.21^{g}	12.40±0.66^{f}	57.23±0.24^{e}	416.17±8.71^{f}
CSWC	3.22±0.26^{d}	18.02±0.08^{c}	19.65±0.59^{cd}	13.33±0.58^{cde}	45.77±0.17^{h}	432.05±6.27^{cde}

[1] Means ± SD based on two replications.

[2] Means within a column with different superscripts are significantly different at $p<0.05$.

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

Soybeans contain 40 – 45 g/100 g crude protein on a dry-weight basis (Yagasaki *et al.*, 1997). Thus crackers with higher proportions of soybean flour had higher protein content. Similar findings have been reported in a study by Akubor and Ukwuru (2003). Although the protein content in plain cassava flour cracker was apparently low; complementation of cassava flour with soybean, bean and wheat flour increased the protein content in the composite mixtures. Whole cassava crackers 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. The cassava-soybean (CSC1 and CSC4) composite crackers contained protein contents that was more than half of the recommended (WHO. 1985) daily per capita intake (40 g) for primary school-age children (6 - 12 years). The contribution of bean to the protein content was highest in the cassava-bean-soybean-wheat (CBSW2) crackers. Del-Rosso and Marek (1996) suggested that, snacks for school age children should provide one-third to one-half of the recommended daily allowance for protein. In light of the above results, if a child eats two crackers, he/she will obtain about 41.84 g of protein which is about 100% of the RDA for protein.

Protein quality

Protein quality is influenced by the concentration of both essential and non-essential amino acids making up the protein. 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. Table 7 summarizes the profile of both essential and non-essential amino acids in the formulated composite crackers.

Table 7: 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	FAO[2]
Asp	42	90	60	66	72	33	31	43	50	54	55	48	60	
Glu	111	148	124	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	
SAA[3]	21	23	22	22	23	27	28	23	22	23	23	24	24	25
AAA[4]	23	63	38	43	48	52	59	38	41	47	40	46	51	63
AAS[5]	32	83	52	59	66	56	28	41	49	52	52	45	55	≥ 65
LAA[6]	Leu	Lys	Leu	Leu	Leu	Thr	Lys	Lys	Lys	Lys	Lys	Lys	Lys	

[1] CC – Cassava cracker. CSC – cassava-soybean cracker. CWC – cassava-wheat cracker, WC – 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

Proportionality pattern of amino acids in foods is the most important determinant of protein quality FAO/WHO (1991). Table 7 shows the proportion of the various essential amino acids in the composite crackers relative to the FAO/WHO/UNU (1985) reference pattern for pre-school and school age children. All the products except 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. 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. 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 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. 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 most limiting amino acids were Lys in WC, CBWC1, CBWC2, CBSWC1, CBSWC2, CBSWC3 and CSWC; Leu in CC, CSC2, CSC3 and CSC4; and Thr in CWC. Lysine and Trp are essential amino acids that are inherently limiting in cereal-based products (Milward, 1999). These amino acid profiles indicated that, while only two composite products (CSC1 and CSC4) could meet the recommended Codex Alimentarius minimum amino acid score of 65%, the other products namely CSC2, CSC3, CWC, CBSWC1,

CBSWC2 and CSWC had 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 food products were designed. These composite products therefore would still be suitable for use as food supplements for school-age children.

4.3.2 Energy content

Results in Table 6 show significant variations ($p < 0.05$) in energy content among the composite crackers. Most composite crackers had about 25% of the energy content recommended per day (1 715 kcal) for primary schoolchildren aged 5–11 years (CWTNHF, 2005). The uppermost energy content was 461 kcal/100 g DM observed in the CSC1 while the lowest was 416 kcal/100 g DM observed in the CBSWC3. Crackers from all blends of cassava and soybean flour had substantial calorific values. Similar values were reported by Onweluzo and Iwezu (1995).

Energy is important for school-age children because it increases concentration and comprehension abilities in class, resulting in good performance. Factors that contribute to short-term hunger for school-age children include, the long distances they walk to school, cultural meal practices that exclude or provide only small breakfasts and/or a lack of family time or resources to provide adequate meals to children before and/or during the school day. Thus the energy content in these crackers would be enough for alleviating short-term hunger at school and would help them to increase attention span and concentration in classes.

4.3.3 Carbohydrate content

Carbohydrate content of the formulated crackers ranged from 16 g/100 g DM in cassava-soybean cracker (CSC1) to 74 g/100 g DM in plain cassava cracker (CC). Results in Table 6 indicate significant variations ($p < 0.05$) in carbohydrate content among the composite crackers. All cassava rich crackers had higher carbohydrate content and contributed enormously to the total energy value. Among the cassava blends, the cassava-bean-wheat cracker (CBWC2) had the highest carbohydrate content (60.6 g/100 g DM) followed by the cassava-bean-soybean-wheat cracker (CBSWC3) which had 57.3 g/100 g DM. In general, crackers from most blends had almost 50% of the carbohydrate content (100 g/100 g DM) recommended daily for primary schoolchildren aged 5–11 years (Food and Nutrition Board, 2004). High carbohydrate content in some of the composite crackers could be associated with inclusion of large proportions of cassava in their formulations, which is a rich source of carbohydrates (Holloway, 1988).

4.3.4 Crude fat content

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 (CSC1) crackers (Table 6). Most of the composite crackers except the cassava-soybean (CSC1) crackers, had fat content less than the maximum fat content (24.1 g) recommended daily for primary schoolchildren aged 5–11 years (CWTNHF, 2005). In this regard, the fat content in the cassava-soybean (CSC1) cracker was significantly higher ($p < 0.05$) than the recommended daily fat intake for primary schoolchildren by 24.7%, while the fat content in the plain cassava (CC) cracker was significantly lower by

50% ($p < 0.05$). Although human body requires dietary fat and essential fatty acids for normal growth and development, USDA (1995) recommends that, adolescents consume not more than 30% of calories from fat, of which, not more than 10% of calories should be derived from saturated fat.

4.3.5 Ash content of the crackers

Ash content, which was an indication of mineral content, was higher in the bean and soybean fortified composites than in the wheat (control) and cassava flour crackers. Bio-fortification thus increased the ash content. Among the composite crackers, the cassava-soybean (CSC1) crackers contained the highest concentration (3.87 g/100 g DM) of ash followed by the cassava-soybean (CSC3) cracker (3.71 g/100 d DM). The lowest ash concentration (2.32 g/100 g DM) was recorded in the plain wheat cracker (WC) and cassava-bean-soybean-wheat (CBSWC3) crackers (Table 6). Ash concentration in plain cassava (CC) cracker was also low (2.49 g/100 g DM) but it increased significantly ($p < 0.05$) when cassava was enriched with bean and soybean flours (Table 6). No specific amount of ash has been recommended for children of primary school age; however, ash content is an important nutritional indicator of mineral content and an important quality parameter for contamination, particularly with the foreign matter (Fennema, 1996).

4.3.6 Crude fiber content of the crackers

Results in Table 6 show significant variations ($p < 0.05$) in crude fiber content among the various cracker formulations. The crude fiber content of the formulated crackers ranged from 18.43 g/100 g DM in cassava-soybean (CSC1) cracker to 7.26 g/100 g DM in plain cassava (CC) cracker. Higher fiber content was observed in crackers containing high proportion of soybean flour, e.g. cassava-soybean (CSC4)

cracker had 15.78 g/100 g DM of fibre while the cassava-wheat-soybean (CSWC) crackers had a fibre content of 13.36 g/100 g DM. Majority of the composite crackers had crude fiber content higher than the minimum amount (15.8 g) recommended daily for primary schoolchildren aged 5–11 years (FNB, 2001). Fiber is an important dietary component in the diet for preventing overweight, constipation, cardiovascular disease, diabetes and colon cancer (Whitney *et al.*, 1990).

4.4 Mineral Composition of the Crackers

The relationship between micronutrient deficiency and cognitive function has recently captured the attention of scientists worldwide (Grantham-McGregor and Ani, 1999). Programs to prevent or alleviate micronutrient deficiencies have been designed to address the problem of micronutrient deficiencies and thus improve cognitive function of children. The concentrations of macro and micro-elements that have been associated with cognitive processes in young children are summarized in Table 8.

4.4.1 Calcium

Calcium is an essential micronutrient for cognitive functioning. It plays a central role in nerve excitability, regulates mood, serves as an intracellular messenger and regulates the neurotransmission (Rosenthal and Goodwin, 1985). Results in Table 8 show that, calcium concentration was highest in the cassava-wheat (CWC) composite crackers (623.47 mg/100 g DM) but lowest in cassava-bean-soybean-wheat (CBSWC2) cracker (415.22 mg/100 g DM). Most composites crackers contained about 40% of the calcium concentration (1300 mg) recommended daily for primary schoolchildren aged 5–11 years (Food and Nutrition Board, 2004).

Table 8: Mineral concentration (mg/100 g) of the composite crackers[1,2]

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

[1] Means ± SD based on two replications.

[2] Means within a column with different superscripts are significantly different at ($p<0.05$).

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

4.4.2 Magnesium

Magnesium is vital for the activity of more than 300 enzymes and plays an important role in neurochemical transmission and muscular excitability (Laires *et al.*, 2004). Magnesium concentration differed significantly ($p<0.05$) among the various composite crackers (Table 8). Magnesium concentration was highest in the cassava-bean-soybean-wheat (CBSWC3) crackers but lowest in the cassava-bean-wheat (CBWC2) crackers. As shown in Table 8, all crackers contained magnesium concentration levels above the 240/mg/100 g DM recommended daily for children aged 7-13 years (Food and Nutrition Board, 2004). However, no harmful effects in human with normal renal function have been reported due to exessive dietary intakes of magnesium.

4.3.3 Iron

Iron is vital for transporting oxygen in the bloodstream and for preventing anemia. For both male and female schoolchildren, the need for iron increases with rapid growth and the expansion of blood volume and muscle mass (Russell, 2001). Iron concentrations differed significantly ($p<0.05$) among the composite crackers. Iron concentration in the crackers ranged from 8.1 mg/100 g DM in cassava-soybean (CSC1) cracker to 6.19 mg/100 g DM in cassava-bean-soybean-wheat (CBSWC2) cracker (Table 8). Crackers made from cassava-soybean flour blends had significantly higher ($p<0.05$) concentration of iron than crackers made from plain cassava (CC) flour. The introduction of wheat in the cassava-soybean-wheat (CSWC) cracker increased iron concentration ($p<0.05$). Generally, iron concentration in all crackers was almost equivalent to the daily recommended intake of 8 mg for

school-age children (Food and Nutrition Board, 2004). Deficiencies of iron and iodine are among the most harmful types of undernutrition with regard to cognition. Iron deficiency renders children listless, inattentive and uninterested in learning. Literature suggests a causal link between iron deficiency anemia and less than optimal learning behaviour for learning (Nokes *et al.*, 1998).

4.4.4 Sodium

Sodium is an electrolyte that helps maintain the body's normal extracellular fluid, acid-base balance and assists in transmission of nerve impulses (Whitney, 1990). The concentration of sodium in the composite crackers ranged from 324 g/100 g DM in the cassava-soybean-wheat (CSWC) to 530 g/100 g DM in plain wheat crackers (WC) (Table 8). Sodium content of 1500 mg has been recommended per day as adequate for children aged 5–13 years (CWTNHF, 2005). In light of the above, only the cassava-soybean crackers (CSC1, CSC3 and CSC4) and cassava-bean-soybean-wheat crackers (CBSWC1) could provide up to one-third of the daily recommended sodium intake per 100 g of the cracker consumed. Modest amount of sodium is recommended for snacks/foods designed for children because excessive salt intake would cause renal solute overload, leading to dehydration and exhaustion.

4.4.5 Copper

Copper is essential in the absorption and utilization of iron during hemoglobin and myoglobin biosynthesis and forms part of several enzymes systems (King, 1993). For the composite crackers, copper concentration ranged from 1.16 mg/100 g DM in cassava-soybean-wheat (CSWC) crackers to 1.74 mg/100 g DM in cassava-soybean (CSC1) crackers. However, there were insignificant variations ($p<0.05$) in copper

concentrations among the various composite crackers (Table 8). This implied that, the variation in the proportions of cassava, soybean, bean and wheat flours used in the formulation of the composites did not significantly affect the concentration of copper in the crackers. Copper concentration of 0.7 mg is recommended per day for children aged 7 to 13 years, however, a concentration of up to 5.0 mg is tolerable (Food and Nutrition Board, 2004). In light of the above results, all composite crackers contained adequate concentration of copper that was within the recommended levels of 0.7 to 5.0 mg/100 g of the composite crackers.

4.4.6 Zinc

Zinc is required as a component of more than 200 enzymes and as a structural component of many proteins, hormones, hormone receptors and neuropeptides. It is also essential for supporting growth and cognitive development in young children (Fabris and Mocchegiani, 1995). In observational studies among elementary school-age children, hair zinc was related to reading ability, suggesting that zinc deficiency interfered with academic performance (Cavan *et al.*, 1993). Results in Table 8 showed a wide variation ($p<0.05$) in the concentration of zinc among the crackers. The highest zinc concentration (4.08 mg/100 g) was observed in the cassava-soybean (CSC1) crackers while the lowest zinc concentration (2.24 mg/100 g) was observed in the plain cassava (CC) cracker. Zinc concentration of 8 mg/100 g is recommended per day for schoolchildren aged 7 to 13 years (FNB-IOM, 2001). In this regard, 100 g of the CSC1, CSC3, WC and CBWC2 crackers would provide almost half of the daily Zinc requirements for schoolchildren.

4.5 Evaluation of Sensory Quality of the Crackers

Sensory evaluation of food products is important for determining consumer acceptability (Samuel *et al.*, 2006). Results of sensory quality evaluation of the various composite crackers are summarized in Table 9. Consumers liked the appearance of CWC, WC (control), CSC4 and CSWC more than the other products. The CSC2, CSWBC1, CSWBC2 and CWBC2 were the least liked composites. Appearance is an important organoleptic attribute that influences consumer acceptance of a product. The panellist liked the appearance of all crackers but preferred that of the cassava-soybean (CSC4) and cassava-soybean-wheat (CSWC) crackers. Possible reason for the preference might be due to increased quantity of soybean in the CSC4 and inclusion of wheat flower in CSWC. The dough prepared from plain cassava flour was more viscous and dense than that from soybean-cassava blends.

In terms of smell, WC (control), CSC4 and CSWC had the most appealing smell ($p<0.05$), while CSC2, CBWC1, CC, CBSWC1 and CBSWC2 composites were the least appealing to the consumers in terms of smell. The colour of the products made from the cassava-soybean (CSC4) and cassava-wheat-soybean (CWSC) flour blends were mostly liked while the composites with bean in the mixture were neither liked nor disliked. Extruded cassava flour formed attractive brownish (chocolate) colored crackers when mixed with soybean flour, while extruded bean flour formed a dull dark color. This colour change might also explain the low rating scores for the crackers containing the bean flour. Extrusion has been reported to have an organoleptic benefit of changing not only the flavor, aroma and texture but also the physical appearance (colour) of cooked products.

Table 9: Sensory quality scores and overall acceptability of the composite crackers[1,2]

Cracker[3]	Appearance	Smell	Color	Taste	Mouth feel	Overall acceptability
CC	3.50±1.11^{b}	3.00±1.14^{cdef}	3.35±1.27^{bc}	2.70±1.28^{ef}	2.82±1.13^{ef}	2.62±1.00^{cd}
CSC1	3.45±0.88^{b}	3.17±1.22^{cde}	3.00±1.22^{cd}	2.90±1.08^{de}	2.77±1.13^{ef}	2.95±1.06^{c}
CSC2	2.42±1.17^{d}	2.52±1.18^{f}	3.35±1.17^{bc}	2.35±1.25^{f}	2.50±1.19^{f}	2.25±1.20^{d}
CSC3	3.17±1.12^{b}	3.22±1.01^{bcd}	2.77±1.02^{d}	3.22±0.93^{cd}	3.22±1.01^{de}	3.05±0.96^{c}
CSC4	4.02±0.95^{a}	3.72±0.76^{a}	4.60±0.50^{a}	4.70±0.46^{a}	3.70±1.10^{bcd}	4.52±0.55^{a}
CWC	4.37±0.84^{a}	3.27±1.39^{bc}	3.10±1.24^{cd}	4.00±0.99^{b}	3.90±0.93^{bc}	4.02±0.99^{b}
WC	4.37±1.08^{a}	4.35±0.74^{a}	3.80±1.16^{b}	4.85±0.36^{a}	4.15±0.70^{ab}	4.67±0.66^{a}
CBWC1	3.12±1.34^{bc}	2.85±1.14^{cdef}	3.67±0.97^{b}	3.02±1.31^{cde}	3.20±1.09^{de}	2.90±1.27^{c}
CBWC2	2.65±1.38^{cd}	3.10±1.15^{cde}	3.70±1.15^{b}	3.42±1.15^{c}	3.45±1.20^{cd}	3.05±1.26^{c}
CBSWC1	2.40±1.24^{d}	2.70±1.22^{def}	3.37±1.05^{bc}	2.82±1.13^{def}	2.80±1.14^{ef}	2.67±1.10^{cd}
CBSWC2	2.37±1.07^{d}	2.62±.07^{ef}	3.30±1.16^{bc}	2.65±1.03^{ef}	2.60±1.17^{f}	2.35±0.98^{d}
CBSWC3	2.97±1.25^{bc}	3.07±1.12^{cde}	3.40±1.26^{bc}	3.30±1.27^{cd}	3.37±1.26^{d}	3.05±1.19^{c}
CSWC	4.07±0.96^{a}	4.32±0.78^{a}	4.62±0.63^{a}	4.42±0.93^{ab}	4.47±0.78^{a}	4.35±1.11^{ab}

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

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

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

The colour of composite crackers containing extruded cassava flour was more preferred to those of plain wheat flour. Colour is an important sensory quality attribute that influences consumer preference especially in children. Children usually prefer bright and colourful foods. Dull colours such as brown and black or colourless products are less preferred by young children.

Composite product CSC4 displayed the most superior taste ($p<0.05$) similar to the control product (WC). The composite products CWC and CSWC were also ranked high by the consumers in terms of taste preference. Products that were liked most in terms of taste were CC, CSC2, CBSWC1 and CBSWC2 (Table 9). On the other hand, the panellist neither liked nor disliked the taste of the plain cassava (CC) cracker, however, the taste improved with incorporation of soybean flour, whereby the panelists liked the taste of the resulting composite products cassava-soybean (CSC4) and cassava-soybean-wheat (CSWC). In a study of supplementary foods for pre-school children mixtures containing beans received low rating scores for colour, aroma and taste (Mosha and Vicent, 2004). In a different study involving the use of mung beans and cowpeas, consumer rating scores were improved significantly 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.

Table 9 data also indicate that, CSWC and WC (control) crackers had the best texture (mouth feel) followed by CWC and CBWC2. Texture is an important sensory attribute that influences customer selection and acceptability of a product. Texture is influenced by the physical characteristics of the flours such as particle size but also

by the fat and protein content. In this regard, composite crackers which had high protein and/or fat content e.g. cassava-soybean (CSC4) were ranked high in terms of mouth feel. As shown in Table 9, there were significant differences ($p<0.05$) in the rating scores for mouth feel for the composite crackers tested. Among the composite crackers, the cassava- soybean-wheat (CSWC) cracker was liked very much in terms of mouth feel compared with the control (WC). The cassava-soybean (CSC4) cracker was liked moderately by the consumers. Lower sensory rating scores for texture were observed in the crackers containing large proportion of cassava flour. Thus inclusion of soybean flour which was high in fat and protein resulted in more tender crackers. Fats and protein have been associated with increased crispiness in baked foods.

Overall, all the composite crackers were acceptable to the consumers and none of the products was ranked as objectionable or unacceptable. Composite products – CSC4 and CSWC were the most acceptable, similar to the WC (control). These findings suggested that, at the 50% level of cassava/soybean flour substitution, the crackers were given high rating scores for all the sensory quality attributes and overall acceptability. Above 50% substitution, lower rating scores were recorded for some of the sensory quality attributes for example appearance, smell and colour.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study has shed light on the potential of using cassava in developing crackers for addressing undernutrition among primary schoolchildren. It has opened new possibilities for utilizing the under-utilized cassava flour in Tanzania. Although plain cassava flour could produce good quality crackers, chemical and sensory analyses have revealed that, various blends of cassava with soybean and bean flour would produce acceptable crackers that are more nutritious. Cassava flour could substitute up to 70% of wheat flour which is used in conventional crackers without adversely affecting the sensory quality of the product. At 50% cassava flour substitution, the protein, fat and energy contents become optimal for supporting growth of schoolchildren. Higher substitution of cassava flour above 50% reduced the protein, fat, and energy contents below the recommended levels. The sensory quality attributes of the crackers at all levels of flour substitution were liked and accepted by the consumers.

The study revealed that, all the composite crackers contained Fe, Mg, Cu, Zn and Ca concentrations in the range that is recommended for primary schoolchildren. The concentrations of the essential minerals were highest in the cassava-soybean (CSC1 CSC3 and CSC4) and cassava-soybean-wheat (CSWC) crackers. Organoleptically, the cassava-soybean-wheat (CSWC) cracker ranked the highest in colour, smell and texture while the cassava-soybean (CSC4) cracker was liked very much in terms of

taste and appearance. Cassava-soybean (CSC4) and the plain wheat were the most accepted crackers and none of the crackers was disliked by the consumers.

Crackers are snacks which are mostly preferred by children in Tanzania. The micronutrient fortified cassava-bean-soybean composite crackers can therefore serve as a vehicle for increasing energy and nutrient intake among primary schoolchildren in Tanzania. Consumption of crackers will help to alleviate short term hunger at school and improve the nutritional status of the children. These in turn will increase school attendance, attention span in class, comprehension and reduce truancy.

5.2 Recommendations

It has been demonstrated in this study that, enrichment of cassava with soybeans and beans and fortification with micronutrients enhances its nutritional value, sensory quality and acceptability. In this regard, efforts by policy makers to improve nutritional status and school outcomes of primary schoolchildren should consider and encourage providing these crackers as mid-morning snacks to students instead of the traditional school meals (school lunch) that are more costly and are served in the afternoon when the children have already experienced the mid-morning hunger. A snack program should focus on the use of locally available raw materials in producing the snacks. This in turn will increase local food production and utilization. The basic foods recommended for use are tubers (cassava, sweet potato, and yam), cereals (rice, maize), fruits, and vegetables. Snacks have an advantage of not substituting family meals the way the school lunches do. Also, the school lunches are typically similar to the meals offered at home, which adds up to the problem of food monotony for the schoolchildren.

The extrusion cooking method used in the preparation of the crackers also improved the quality of the products with respect to appearance and mouth feel. Therefore, small food processing industries in the country should adopt the extrusion technology in the production of confectionary products from cereals and root crops.

It is also recommended that, further research should be done to assess the efficacy of the composite snacks in improving the nutritional status and school performance of primary schoolchildren. This will affirm the importance of school snack program in improving the children's nutritional status and overall school performance.

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APPENDICES

Appendix 1: Sensory evaluation form

Name..... Age..... Sex..... Date.....

Please choose the term that best reflects your attitude towards the products by writing a number under the product code. Test the sample from left to right.

Key: 5-Like very much, 4-Like moderately, 3-Neither like nor dislike, 2-Dislike moderately, 1-Dislike very much

SAMPLES	APPEARANCE	SMELL	COLOUR	TASTE	MOUTH FEEL (TEXTURE)	OVERALL ACCEPTABILITY
960						
840						
750						
660						
603						
201						
540						
430						
370						
280						
120						
507						

Comments .....

Appendix 2: Ethical clearance

THE UNITED REPUBLIC OF
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CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled Evaluation of the efficacy of cassava bean composite supplementary snacks in improving the nutritional status of primary school children (Sadick A M), whose Principal Investigator is Asha M Sadick has been granted ethics clearance to be conducted in Tanzania

The Principal Investigator of the study must ensure that the following conditions are fulfilled

1. Progress report is made available to the Ministry of Health and the National Institute for Medical Research, Regional and District Medical Officers after every six months
2. Permission to publish the results is obtained from National Institute for Medical Research
3. Copies of final publications are made available to the Ministry of Health and the National Institute for Medical Research
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine

Name: Dr Andrew Y Kitua

Signature

CHAIRMAN
MEDICAL RESEARCH
COORDINATING COMMITTEE

Name: Dr Deo M Mtasiwa

Signature

CHIEF MEDICA L OFFICER
MINISTRY OF HEALTH, SOCIAL WELFARE

CC: RMO
DMO

Appendix 3: Concentration of vitamin/minerals per 2.9 g of premix

Item	Concentration
Vitamin C	60.00 mg
Vitamin B_{12}	6.00 mcg
Biotin	300.00 mcg
Pantothenic Acid	10.00 mg
Vitamin D_3	400.00 IU
Vitamin E	30.00 IU
Folic Acid	400.00 mcg
Vitamin K	80.00 mcg
Vitamin B_3	20.00 mg
Vitamin B_6	2.00 mg
Vitamin B_2	1.70 mg
Vitamin B_1	1.50 mg
Vitamin A	5000.0 IU
Magnesium	300.00 mg
Selenium	70.00 mcg
Copper	2.00 mg
Calcium	500.00 mg
Iodine	150.00 mcg
Zinc	10.00 mg
Phosphorus	390.00 mg
Iron as iron-EDTA	12.00 mg