FORMULATION, NUTRITIONAL EVALUATION AND ACCEPTABILITY OF CASSAVA-SOYBEAN BASED WEANING FOODS SUPPLEMENTED WITH FINGER MILLET

BY

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ABSTRACT

A study was conducted to establish the proportions of cassava, soybean and finger millet that could meet nutritional and acceptability qualities of weaning foods. Five different weaning foods were formulated using soaked-germinated-roasted, soaked-fermented, soaked-dehulled-roasted, soaked-cooked and soaked-dehulled-dried soybeans, fermented cassava and malted finger millet. Each soybean processing technique was made into three sets of proportions as 60:20:20, 50:30:20 and 50:40:10 of cassava: soybean: finger millet, respectively. Proximate composition and minerals were analyzed using AOAC (1995) methods. There was significant difference ($p<0.05$) among the processed soybean ingredients and formulations in nutrients content, soaked-fermented treatment being superior. Fermented and unfermented cassava was not significantly different ($p>0.05$) in nutrient content. Nutrients in the formulations increased with increase of soybean proportions. The 60:20:20 contained 11.08-12.4% protein, 4.9-7.2% fat, 2.8-6.0% fibre, 1.4-2.1% ash, 76.1-78.2% carbohydrate and 403.4-414.4 kcal/100g energy. The 50:30:20 formulations had 15.3-17.2% protein, 6.8-9.7% fat, 3.5-4.6% fibre, 1.6-2.6% ash, 66.8-70.2% carbohydrate and 406.6-426.3 kcal/100g, while the 50:40:10 contained 18.3-21.0 % protein 9.5-12.3% fat, 4.2-6.0% fibre, 2.0-3.1% ash, 59.9-63.8% carbohydrate and 414.6-441.5kcal/100g energy. Amino acid was predicted in the formulations. Threonine was found to be the most limiting amino acid in all the formulations. Mineral content (mg/100g) increased with increase of soybean proportions in the formulations. The 60:20:20 had 116.7-121.3 calcium and 3.27-4.04 iron. Proportions 50:30:20 contained 136.00-160.33 calcium and 3.61-4.70 iron and the 50:40:10 contained 143.53-163.67 calcium and 3.79-4.98 iron. Formulations with 50:30:20 proportions had suitable nutrients content with protein above 15%. Soaked-dehulled-roasted soybean was superior on the improvement of flavours followed by soaked-cooked soybean. Soaked-germinated-roasted was poor on sensory qualities. The products were 80% acceptable to use in weaning food formulations. The HCN was 8.3 and 22.1 mg/100g in fermented cassava and malted finger millet, respectively before formulation. Soybean processing reduced tannins by 47.6 to 59.5 % and phytates by 67.1 to 68.9 %. The formulations need to be supplemented with micronutrients and more studies are needed to assess the protein quality of the products and availability of the micronutrients.

DECLARATION

I, Agnes Njau Mneney, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted for a degree award in any other University.

Signature:..

Date:...18/10/2005.................

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ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
B.C.	Before Christ
BBI	Bowman-Birk Inhibitor
CIAT	Centro Internacional de Agricultura Tropical
CIS	Until 1991, areas of USSR
COSCA	Collaborative Study of Cassava in Africa
CRSP	Collaborative Research Support Program
DIAS	Division and Information Sciences Division
EDTA	Ethylenediamine tetra acetic acid
ETEC	Enterotoxigenic *Escherichia coli*
FAO	Food and Agriculture Organization of the United Nations
F-Ca	Fermented-cassava
GIEWS	Global Information and Early Warning Systems on Food and Agriculture.
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
HCN	Hydrogen cyanide
HNO_3	Nitric acid
KOH	Potassium hydroxide
M-Fm	Malted-fingermillet
Na_2OH	Sodium hydroxide
PEM	Protein-Energy Malnutrition
PEU	Protein-Energy Under nutrition
Ra- So	Raw -soybean

SBTI	Soybeans Trypsin Inhibitor
S-C	Soaked-cooked
S-D-Dr	Soaked-Dehulled-dried
S-D-R	Soaked-dehulled-roasted
S-F	Soaked- fermented
S-G-R	Soaked-germinated-roasted
TBS	Tanzania Bureau of Standards
TZS	Tanzania Standard
U-Ca	Unfermented cassava
UNICEF	The United Nations Children's Fund
USA	United States of America
WHO	World Health Organization of the United Nations

CHAPTER ONE

1.0 INTRODUCTION

Cassava (*Manihot esculenta,* Crantz) is emerging as a dominant staple of primary or secondary importance in many developing countries of humid and sub-humid Africa and elsewhere (Okigbo, 1995). Being drought resistant, it is sometimes a nutritionally strategic famine reserve crop in areas of unreliable rainfall.

It is an important root crop, which represents an inadequate, explored commodity for both nutritional and economic development. It accounts for about a third of total staples produced in Sub-Sahara Africa (FAO, 1986). According to the Ministry of Agriculture and Food Security (1991), the crop is well integrated into the Tanzanian crop production systems. It is among the more important staples in many zones in Tanzania (COSCA Tanzania, 1996). Cassava plays an important role in food security and is mainly regarded as a subsistence crop for low-income families or as a famine reserve crop, although it is more important due to its low cost source of energy (Hahn, 1982). Deficiencies and limitations of cereal grain supply and the fact that price is too high in many areas of the world, including Tanzania, necessitate the emphasis on the use of more low cost cassava in the diet including weaning foods. It is the second priority ranking in national crop research and number one in southern, coastal and lake zones of Tanzania (Msabaha *et al.,* 1986). Cassava tuber is mainly a supply of carbohydrates and little else. It cannot be considered as a balanced food and diet (Onwueme, 1982). However, its various food forms in different parts of the world, including Tanzania, are well established in the consumption habit of the growing population, where it is produced. During critical shortage of cereal staples, these food forms are also employed in weaning regardless of the nutritional deficiencies, high viscosity and the weaning food nutrients and texture needs. Cassava must be made to supply the other nutrients required for infant growth through blending with nutritious legumes like soybean and micronutrient rich cereals like finger millet (Saidu *et al.*, 2003). The formulated and/or processed and enriched cassava-based weaning food products shall not meet only the nutritional needs but also acceptability quality as determined by the taste panel before being available or recommended for mass feeding. These may lead into the solution of the weaning nutritional problem for the low income families by being inexpensive, easy to obtain and easy to prepare.

In this study more emphasis was to establish cassava-soybean and finger millet proportions that will meet the nutritional and acceptability requirements for weaning food.

1.1 Problem statement

Tremendous problems in infants and young children exist. The most important nutritional deficiency diseases in Tanzania include Protein-Energy Malnutrition (PEM), iron, and vitamin A and Iodine deficiency disorders. About 50% of young children in Tanzania suffer from Protein-energy undernutrition (PEU) while more than 45% of the children under the age of five suffer from various micronutrient deficiency disorders. The immediate cause of these conditions is inadequate intake and poor utilization of nutrients (Mosha *et al.*, 2000). The solution to PEM problems does not call for expensive protein calorie concentrate or rather factory-processed foods. However, emphasis shall be on the formulation of special low cost weaning foods that will be rich in energy, protein and micronutrients from low cost locally available staples (Gahlawat and Sehgal, 1994).

1.2 Justification

Cassava is a potential low cost resource for combating energy malnutrition. It is however, deficient in most other nutrients like protein, minerals and vitamins. It has been underutilized in this regard to eradicate energy malnutrition. On the other hand, soybean is a potential source of protein and it supplies almost twice or more of the common dietary protein sources like legumes (beans, peas, cowpeas). In addition, it has high fat content that could assist in minimizing energy malnutrition. This potential crop has not been fully exploited. Finger millet, on the other hand, is a rich source of calcium and iron and other common nutrients like the B group vitamins. Its incorporation in weaning foods will specifically raise the iron status to alleviate anaemia. As many households cannot afford milk, a common rich source of calcium, finger millet could help towards minimizing this deficiency, especially in resource poor households in the developing countries (where more than 80% are rural-based).

Infant foods need to be specially prepared with low paste viscosity, high energy density, adequate and quality protein as well as essential micronutrients using locally available staples. The optimum blending ratios to produce nutritionally balanced weaning foods based on such common low cost staples have not been established. Studies in this area could help to achieve the nutritional needs of infants and young children. Soy-based and cassava-based weaning foods have limited acceptability partly due to flavour and texture, respectively. Studies in this regard, for formulated products thus seem essential. The formulated foods will at least combine some desired characteristics of high nutrient density and acceptability at low cost to meet the requirements for growing infants.

1.3 Objectives

1.3.1 Main objective

To develop low-cost nutritious and acceptable cassava-soybean-finger millet based weaning foods.

1.3.2 Specific objectives

i) To establish optimal ratios of formulations based on five products of cassava-soybean-based weaning food supplemented with finger millet in different proportions.

ii) To establish the nutritional composition and relative safety of different weaning foods formulated from cassava, soybean and finger millet flours prepared using different processing techniques

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Weaning and weaning foods

2.1.1 Weaning

King and Burgess (1993) defined weaning as the process of introducing foods other than breast milk to a child and gradually increasing the amount, so that eventually the child gets enough energy and nutrients from ordinary family food. Thus, weaning is the process of gradually adding foods to the breast milk in a child's diet. Weaning starts at around six months of age when breast milk becomes inadequate for normal healthy growth (Gahlawat and Sehgal, 1994). Weaning food administration is increased little by little whilst the child gets slowly decreasing breastfeeding so that eventually the child gets adequate energy and nutrients from the family table foods, mostly at the age of two or above (King and Burgess, 1993).

2.1.2 Weaning foods

The first foods for the baby are referred to as weaning foods (King and Burgess, 1993). These foods should be nutritionally well balanced with appropriate mixture rich in protein, energy and micronutrients (Kshrisagar *et al.*, 1994). They should have a soft texture with very low fibre content and specially prepared for the baby to swallow. Weaning foods should also be clean, free from pathogenic microorganisms and parasites and easy to prepare (Gahlawat and Sehgal, 1994).

Their purpose is to supplement breast milk to make the young child to have enough energy, protein and other nutrients to allow normal growth of the child. Impaired growth, retarded physical and mental development, a high frequency of infections episodes and a variety of nutritional deficiencies may result from lack of these foods during early stages of a child development.

Most of the industrial-processed weaning foods are pre-cooked, roller-dried mixtures based on of cereals, legumes or other protein-rich foods with varying proportions of milk solids and fortified with vitamins and minerals (Desikachar, 1982). Thus these foods are rich in energy and other nutrients. However, they are often too expensive and difficult for the majority of families to obtain (Reddy *et al.,* 1990; Gahlawat and Sehgal, 1994). Children most at risk of under-nutrition are from poor families who cannot afford expensive industrial processed foods. Traditionally processed weaning foods having all the sufficient nutrients in sufficient proportions and acceptable colour, texture and flavour they are difficult to achieve. The solution of infant nutritional problem may be to put more emphasis on the use of low cost weaning foods that should at least combine some of the desired characteristics of high nutrient density, low bulk property basing on locally available resources, which can be easy to prepare at home (Reddy *et al.,* 1990; Kshirsagar *et al.,* 1994; Gahlawat and Sehgal, 1994). The choices of the formulations should suit local needs, cultural patterns and ecological circumstances.

These "unprocessed" weaning foods (home made weaning foods) are normally made from staple foods available at the market or home gardens as main ingredients preferably cereals, plantains and/or cassava. A protein supplement from a plant or animal food, for example, beans, milk, meat, chicken, fish and eggs can be used. While the industrialized countries' weaning foods generally contain milk or more often are designed to be mixed with milk at the time of preparation, in most of developing countries milk has to be imported and if produced locally it is too expensive for the majority of families to afford.

Thus, in developing countries high protein content could be achieved by the use of legumes such as soybeans that are good and low-cost protein sources.

2.1.3 Weaning food formulation

Generally, weaning foods are presented in the form of dry flour with high nutritional value in terms of energy and protein content, good supplementation of vitamins and minerals, good acceptability to consumers, low price and processed using locally produced ingredients. The formulation should be based on the principle that the child will consume an average of 100 g dry weight per day to have a daily minimum nutritional requirement recommended to a child to achieve normal growth (Gahlawat and Sehgal , 1994).

The weaning food forms are to be suitable for easy preparation at the time of feeding by either addition of small quantities of freshly boiled water or by adding water and boiling for a short time to obtain gruel or porridge of proper consistency (Kshirsagar *et al.*, 1994). The intensive study on the formulation of cassava-soybean based supplemented with malted finger millet may lead into having low cost weaning food, which is rich in energy and nutrients. This may suit local needs and cultural patterns as well as ecological circumstances and therefore it will be easy for the majority of families to obtain.

2.2 Nutritional status of weaning foods of Tanzania

An average of 3% children under the age of five years suffer from protein–energy malnutrition in developing countries (Kishrsagar *et al.,* 1994). In Tanzania, about 50% of young children suffer from protein–energy under nutrition (PEU) (Kavishe, 1992; Tanzania Food and Nutritional Centre, 1993). Micronutrients deficiencies account for another form of nutrient deficiencies and are widely spread among infants and young children. This was reported to account for the high rates of child malnutrition, mortality and morbidity among the children (Ministry of Health, 1997). Household food insecurity and/or inadequate childcare system are considered as immediate cause of undernutrition while deeper-rooted basic factors relate to socio-economic conditions (Kavishe, 1992). Birth weight of most Tanzanian children is above recommended level of 2.5 kg implying that they start life in sound health (Mosha *et al.*, 1998). However, growth retardation starts at weaning and/or immediate thereafter. A serious problem at this period is protein-energy and micronutrients deficiencies as weaning foods consumed do not supply adequate amounts of these nutrients as shown in Tables 1 and 2 (Mosha *et al.*, 2000).

Table 1: Proximate composition (g/100g) and energy content (kcal/100g) of various home-made and commercial weaning foods

Food	Energy	Protein	Fat	Ash	Fibre	Carbohydrate
Maize	457.09	13.34	13.13	2.14	7.67	71.39
Cassava	389.30	6.00	2.22	5.44	16.00	86.33
Millet	419.40	32.84	5.20	1.64	3.39	60.31
Sorghum	408.61	14.60	3.32	2.00	4.20	80.08
Cerelac-1	419.24	15.90	8.72	2.36	1.54	69.29
Cerelac-2	426.96	15.90	8.92	2.97	1.03	70.77
Lactogen-1	509.91	16.60	24.95	3.71	1.00	54.74
Lactogen-2	478.16	22.27	19.59	4.95	1.30	53.19
Codex Stan 156	483.90	14.52-37.7	14.52-41.13	NS*	NS*	41.13-73.90
TZS 180:1983	NS*	15.2	≤ 8.15	≤ 5.43	2.17	48.90

Source: Mosha *et al.* (2000).
NS* = Not specified.

Table 2: Mineral content (mg/100g) of various home made and commercial weaning foods of Tanzania (on dry matter basis).

Food	Ca	Fe	P	Zn
Maize	18.47	9.04	27.42	1.02
Cassava	115.32	12.08	83.95	2.81
Millet	319.79	23.36	144.33	2.79
Plantain	37.35	6.18	99.51	1.25
Millet-composite	115.92	7.87	73.76	1.60
Sorghum	40.00	5.93	350.00	2.77
Cerelac-1	429.00	2.50	370.00	3.80
Cerelac-2	505.00	3.80	330.00	3.42
Lactogen-1	570.00	5.90	440.00	3.80
Lactogen-2	770.00	8.40	600.00	3.80
Codex Stan 158	≥ 435.51.	4.84	290.34	2.42
TZS180:1983	NS*	≥ 10.87	NS*	NS*

Source: Mosha *et al.* (2000).
NS* = Not specified.

Most of traditional home-made weaning foods and certain commercial weaning products were reported to be deficient in energy balance and micronutrient density. They have been reported to have low content of fat, ash, iron, calcium, zinc and phosphorus (Mosha *et al.*, 2000). Children, pregnant and lactating women, are the most vulnerable to malnutrition in different parts of Tanzania and Africa due to their special dietary needs (Mosha *et al.*, 2000). Children with PEM often come from poor families that do not produce enough food or income to purchase adequate food. Sometimes malnutrition may not be due to the household lack of food but because the parents lack knowledge of the special food needs of young children and how to prepare safe and nutritious foods. In some cases parents are not always aware of the relationship between insufficient food intake and malnutrition (Kavishe, 1992).

Most of traditional weaning foods of Tanzania are based on low cost, readily available and easy to prepare starchy staples usually cereals such as maize (*Zea mays*), sorghum

(*Sorghum bicolor*), finger millet (*Eleusine coracana*) and rice (*Oryza sativa*). On rare cases, non-cereal starchy staples such as cassava (*Manihot esculenta*), round potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), yams (*Dioscorea*) and p lantains (*Musa paradisiaca sapientum*) have been used in weaning food formulations when cereal supply is limited or too expensive (Mosha *et al.*, 2000). Although nutritional problems associated with the use of non-cereal starch staples in weaning food formulation have been reported by Seenappa (1987) and Mosha (1984) and the nutrients deficiencies in most of cereal staples are well reported, the incorporation into traditional weaning food does not take into consideration the problems associated with these food staples.

2.3 Cassava

Cassava (*M. esculenta*) that is also called manioc, yucca or tapioca is a native to South America and Southern and Western Mexico. It is considered as one of the first crops to be domesticated and through archeological evidence. It was reported to grow in Peru 4,000 years ago and in Mexico 2000 years ago. It was adapted to the zone within latitude 30° N and S of the equator at an elevations of not more than 2000 m above sea level, in temperatures ranging from 18-25°C. It requires rainfall of 50-5000 mm annually and is adapted to poor soils with pH 4-9 (Okigbo, 1995).

Cassava spread to other parts of the world and it was introduced into West Coast of Africa and Zaire in the late sixteenth century probably in slave ships. It was introduced into East Africa (Madagascar and Zanzibar) via Reunion by the end of the eighteenth century. It was widely grown in Africa and South-East Asia by the 1850s (Okigbo, 1995).

2.3.1 Importance of cassava

Cassava is considered as an important low cost energy source food crop having high drought tolerance and the root can be stored underground for several weeks or even months and harvested when required. In semi-arid areas, it is one of the most important subsistence food crops (Ministry of Agriculture and Food security, 1991). The crop has ability to recover from severe climatic stress, particularly drought or pest and disease attack, when favourable conditions return. It is thus regarded as an extraordinary hardy plant. It is relatively adaptable to traditional farming systems and easy to cultivate. The harvest is year round and ensures food against other crop failures mostly cereals (Hahn *et al.*, 1986). The cassava root is more important than being mainly a subsistence crop of low-income families or as famine reserve. It is characterized by having significantly higher calories than other staple crops such as rice, wheat, maize millet and sorghum. During planting, the material used for propagation is the stem cutting, non-edible and otherwise useless part of the plant, which does not limit the farmer to consume his entire harvest of roots (Onwueme, 1982). Cassava crop is not seasonal bound. It can be planted anytime of the year in any region within the country and in most tropical areas, regardless of scanty rainfall provided there is enough moisture at planting.

The overall production cost is relatively very low compared with other staple crops such as cereals. It requires low labour and investment, easy cultivation with high productivity (Hahn *et al.*, 1979; Ikpi *et al.*, 1986). The crop requires very little attention and farmers can obtain reasonable good yield even if it has been neglected (Onwueme, 1982). It requires very little weeding when planted in optimal plant population (Okigbo, 1995). The crop is considered to have effective ecological adaptation, and is relatively hardy plant particularly with respect to drought. It is superior, competitive over other staples to grow well in depleted soils where even weeds will not grow well. It can be planted even after the harvest of cereal crops regardless of scanty rainfall (Hahn *et al.*, 1986).

2.3.2 Cassava as a major staple in the world

Cassava is a major subsistence staple with global utilization as food that contributes to the direct nutrition and livelihood of up to 500 million people. It is the fourth most important source of energy after rice, wheat and maize. The world's annual production of its starchy roots reaches more than 158 billion tons of which 58 % is used for human consumption, 22 % for animal feeds and 20 % for other uses (Montero, 2002). Although it is a native to tropical America, it is now mainly produced in Africa (Montero, 2002) as reported by FAO/GIEWS (2001) in Table 3. Its bulk is consumed in Africa in the form of fresh roots and processed products such as *gari, foufou altieki, makopa,* etc. (COSCA Tanzania, 1996).

Table 3: World production of cassava roots (million tons) in 1999-2001

	1999	*2000*	2001
AFRICA	***92.4***	***92.7***	***90.9***
Congo Dem. Rep.	16.5	16.0	13.5
Ghana	7.8	7.5	7.8
Madagascar	2.5	2.2	2.4
Mozambique	5.4	4.6	4.5
Nigeria	32.7	33.9	34.0
Tanzania	7.2	5.8	5.0
Uganda	3.3	5.0	5.5
ASIA	***50.9***	***50.5***	***49.4***
China	3.6	3.6	3.8
India	6.1	6.2	6.2
Indonesia	16.5	15.7	15.5
Philippines	1.8	1.8	1.8
Thailand	20.3	20.2	19.2
Viet nam	1.8	2.0	2.0
LATIN AMERICA AND CARIBBEAN	***29.2***	***32.1***	***33.5***
Brazil	20.9	23.4	24.6
Colombia	1.8	1.9	2.0
Paraguay	3.5	3.5	3.7
WORLD	***172.6***	***175.5***	***174.0***

Source: FAO/GIEWS (2001).

2.3.3 Cassava production and utilization in Tanzania

Cassava (*M. esculenta*) is an important subsistence crop in Tanzania especially in the arid and semi arid areas and sometimes is considered as famine when cereal fail due to its drought tolerance and the fact that the roots can readily be stored under the ground (Ministry of Agriculture and Food Security, 1991). It is an important food security crop and its production is becoming more important (Table 4) due to its drought resistant and storage (in ground) characteristics. Thus the crop has added advantage over other major grain staples in dry areas.

Table 4: Production and demand of main food crops ('000' tons) from 1993/94 to 2000/2001 in Tanzania

Season	Production				Demand			
	Cassava	Maize	Paddy	Sorghum/ millets	Cassava	Maize	Paddy	Sorghurm
1993/94	1802	1812	614	696	1013	2557	401	912
1994/95	1492	2567	722	838	1013	2557	401	912
1995/96	1498	2663	734	1239	1131	2539	412	913
1996/97	1425	1879	528	1151	1234	2568	450	978
1997/98	1532	2726	548	1078	1229	2750	442	1131
1998/99	2209	2805	865	743	1229	2750	442	1131
1999/2000	2236	2739	934	728	1230	2764	455	960
2000/2001	2017	3348	1010	688	1230	2764	455	960

Source: The United Republic of Tanzania (2001).

It was reported that 84% of the total production of cassava in the country is utilized as human food the remaining percentage are for other uses like starch production, livestock feed and export (Kapinga *et al* 1998). The estimated annual growth of cassava consumption demand for period from 1980-2000 was 3.4 % that was similar to estimate for maize (Table 5). Cassava is produced in all regions of Tanzania. The main producing areas are Mwanza, Mtwara, Lindi, Shinyanga, Tanga, Ruvuma, Mara, Kigoma, Coast Regions and most regions in Zanzibar as it was shown in appendix 1 (IITA, 2002). Thus cassava production is more concentrated in Lake zone, Eastern zone, Southern zone Zanzibar (Ministry of Agriculture and Food Security, 1991). The crop is well integrated into the Tanzanian crop production systems and has been given second ranking in national research (Ministry of Agriculture and Food Security, 1991). It plays an important role as a food security crop.

Over decades high production of cassava was limited due to the presence of government policy that was not very clear on agricultural food crops. Research on food crop was not given an emphasis as compared to cash crops, thus low level of funds were allocated for food crops and the least of it was allocated to cassava research development of its infrastructure. The present government policy is to expand production of domestic food crops for ensuring food security and exports crops for increased earnings. There has been a shift towards cassava particularly in the drought prone areas because of the need for more drought tolerant crops (Ministry of Agriculture and Food Security, 1995) and sensitization of people in adopting cassava in their cropping system. Cassava is considered as an emergency food crop when cereals fail (Kapinga *et al.,* 1998) and inferior food crop by many consumers, hence its acceptability is difficult in some regions and in middle and high socio-economic classes (Hahn *et al.*, 1986).

The presence of cassava pests such as green mites of 1970-1980 was another limitation of cassava production. Varieties that were found to be pest resistant were associated with poor yielding and flowering ability that made them to be unaccepted by the farmers and therefore made improvement impossible (Kapinga *et al.*, 1998).

Low level of processing and lack of alternative convenient products in cassava growing areas are also considered as limitation in utilization. Traditional processing methods are considered to be poor and could not meet the nutritional needs. The weaning foods for most of cassava growing zones are not yet developed except in Mtwara region under CRSP programme. There is no proper storage facility available for processed and dried cassava products (Kapinga *et al.*, 1998).

Forms of cassava products in Tanzania are very few compared with other African countries. The range of cassava food products was very narrow. Cassava was transformed predominantly into nonconvenient food products that could not compete effectively with food grains in the market. Therefore did not have as many market opportunities as much as cassava products made in other countries, especially in West or Central Africa (Msabaha, *et al.*, 1996; FAO, 1986; COSCA Tanzania, 1996). In more than 90% of the representative villages in Tanzania, the most important cassava product was chips/flour (*makopa*) while the other products of primary importance were starches, alcohol and fresh root (COSCA Tanzania, 1996).

In urban areas where there is an assured market, cassava is mainly consumed in fresh form, a product that is very susceptible to biodegradation hence kept for a few days after harvest. Some of good cassava varieties have been observed to be associated with high cyanide content that hinders its utilization. The farmers in Coastal areas and Zanzibar reject the good cassava varieties due to levels of cyanide content (COSCA Tanzania, 1996). This issue of hydrocyanic acid is a limitation on the use of cassava in fresh form as was reported by Okigbo (1986). In some cases cyanide can be so high in some varieties such that can be made safe only after detoxification through processing (FAO, 1986). In the view of country's realization of the importance of cassava in food, the emphasis is now to formulate various forms of cassava products including weaning foods to be adopted by the community where it is consumed (Ministry of Agriculture and Food Security, 1991).

2.3.4 Nutrients composition of cassava

Cassava is a starchy staple whose roots are very rich in carbohydrates, a major source of energy. It is the highest producer of carbohydrates among crop plants with perhaps the exception of sugarcane. The chemical composition varies in different parts of the plant and according to variety, location, age, methods of analysis, and environment conditions (CIAT, 2001). The root is very rich in carbohydrates 64-72 % of which is made up of starch. They are grossly deficient in protein, fat and some minerals and vitamins as indicated in Table 4. Compared with other food staples, cassava is of lower nutritional value than the cereals, legumes and even some other root and tuber crops such as yams (Okigbo, 1995). Cassava is reasonably rich in calcium and vitamin C but thiamine, riboflavin and niacin content are not as high (Table 5) (Okigbo, 1995).

Table 5: Nutrient composition of cassava root (on dry matter basis)

Macronutrients (%)		Micronutrients (mg/100g)	
Dry matter	35.00	Vitamin A	0.02
Crude protein	1.10	Thiamine (B1)	0.05
Non-nitrogenous extracts	31.70	Riboflavin (B2)	0.03
Ether extract	0.47	Niacin	0.06
Crude fibre	1.10	Ascorbic acid	30.00
Total ash	0.70	Iron	17.00
Calcium	0.10	Copper	2.00
Phosphorous	0.15	Zinc	14.00
Potassium	0.25	Sodium	76.00
Magnesium	0.03		

Source: CIAT (2001).

2.3.5 Cassava processing

Cassava roots are harvested as required after 8 months, one year or two years depending on variety. Once harvested, cassava roots begin to deteriorate rapidly, often within two days due to enzymic changes. The decaying/discoloration (brown to darkish-blue) of tissues and /or streaking of the roots indicate the deterioration of cassava roots. Such roots are neither any longer fit for consumption nor industrial processing (CIAT, 2001). On leaving the tubers in the ground beyond maturity, the starch content increases to a stage where lignifications sets in so that roots become tough, fibrous and woody. Cassava is therefore processed soon after harvest and then traditionally preserved dry as whole tubers, chips, slices or milled product (FAO, 1997; CIAT, 2001).

2.3.5.1 Peeling

Peeling is always done manually with a knife. Peeling in the dry season is more difficult than in wet season because the skin adheres more strongly to the dry flesh of the roots and loss of dry matter is high (FAO, 1997).

2.3.5.2 Soaking /fermentation

Peeled roots are either cut into small pieces or washed as whole ready for soaking and fermentation. Peeled and washed roots are soaked in tap water and fermented in either wet or dry state for 2-3 days in warm season compared to 7-10 days in the cold season. This is a primary step in the processing since it removes bitterness improves flavour and soften the roots for subsequent grinding or pounding (FAO, 1997).

2.3.5.3 Drying

Cassava chips, pounded or whole roots are dried in the sun although during the rainy season or periods of cold weather cassava may be dried over a fire. Sun drying in the dry and hot season usually takes two to three days but in the rainy season the period may extend over a week (FAO, 1997).

2.3.5.4 Pounding and milling

In the rural areas cassava is pounded traditionally using a pestle and mortar but access to hammer mills pounding is possible nowadays in many parts of the country. The flow diagram for this traditional cassava processing is shown in Figure 1.

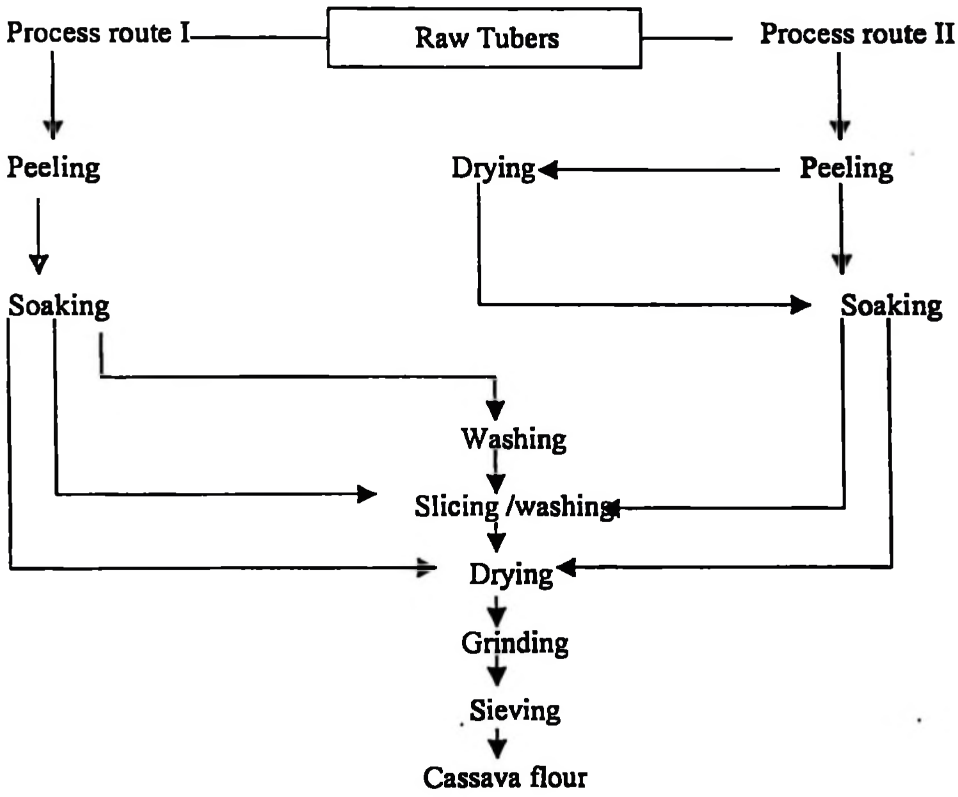

Figure 1: Flow diagram of alternative methods for traditional cassava processing into cassava flour.

Source: FAO (1997).

2.3.6 Effect of cassava processing on nutrient composition

2.3.6.1 Peeling

Peeling removes unwanted parts of raw materials. It significantly reduces the levels of poisonous phytotoxins such as cyanogenic glycosides (Nout and Ngoddy, 1997). However, the peel of cassava contains slightly more protein than that found in the flesh. Peeling results in loss of parts of the valuable protein component of the root (Okigbo, 1995).

2.3.6.2 Soaking/fermentation

Fermentation being a primary step in the processing of the roots, removes bitterness (cyanogenic glycosides), improves flavour and softens the roots for subsequent grinding or pounding. It also results in protein enrichment by a factor of some 6-8 from the initial level of 1-2 % (Hendershot *et al.*, 1972 cited by Okigbo, 1995). Cassava is reasonably rich in calcium and vitamin C but low in riboflavin, thiamine and niacin content, but large proportions of these nutrients have been reported to be lost during processing (Okigbo, 1995).

Fermentation process is either wet or solid state. It is the method of subjecting food to the action of microorganisms or enzymes that cause desirable biochemical changes and significant modification of food. The process goes back many thousands of years, with early evidence of the alcoholic fermentation of barley to beer and grapes to wine. Fermentation process may have started as natural processes in which nutrients available and environmental conditions selected particular microorganisms that modified and preserved the food (Campbell-Platt, 1994). The process represents one of the oldest known uses of biotechnology and plays at least five roles (Steinkraus, 1996).

These include:

(i) Enrichment of the diet through development of diversity of flavours, aroma and texture in food substrate.

(ii) Preservation through lactic acid, alcoholic, acetic acid and alkaline fermentations.

(iii) Biological enrichment of food substrate with protein, essential amino acids, essential fatty acids and vitamins.

(iv) Detoxification and removal of antinutritional factors.

(v) Decrease in cooking time and fuel requirements.

The bitterness of cassava is due to the presence of natural toxic constituents such as cyanogenic glucoside, that require detoxification before cassava is consumed (Okigbo, 1986). Apart from the biological enrichment of cassava roots with protein, amino acid and vitamins through fermentation process, the prime role is to render the roots non-toxic by this process. Fermentation of cassava roots by soaking (which is very popular in Africa) is one of the effective cyanogen removals and, when drying follows this, especially sun drying, it is possible to obtain a cyanogen-free product (Oke, 1994). During soaking cyanogenic glucosides break down through enzyme hydrolysis rendering the root non-toxic. Boiling, frying, cooking and drying directly are inefficient methods for cyanogen removal. Traditional methods always tend to combine one or two of the efficient methods with other less efficient to give almost cyanogens free product (Oke, 1994).

2.3.7 Classification of traditional cassava processing methods

According to Okigbo (1995) these methods may be categorized as follows:

1. No special detoxification techniques applied

(a) Totally unprocessed (i.e., eaten raw).

(b) Simple cooking techniques only (as used for nontoxic starch staples).

- (i) Boiling, stewing, etc.
- (ii) Roasting, baking.
- (iii) Frying.

(c) Sun-drying

- (i) Sun-drying without subsequent processing.
- (ii) Sun-drying with subsequent processing such as different types of milling, grinding, etc.

(d) Kiln or hot air drying

(i) Kiln or hot air drying without subsequent processing

(ii) Kiln or hot air drying with subsequent processing

2. Special detoxification techniques applied

(a) Detoxification by solution

(i) Soaking of whole roots or large pieces

(ii) Soaking in static water.

(iii) Soaking in running water.

(iv) Soaking in salty water.

(b) Soaking after comminution (subdivided as for detoxification by solution)

(c) Boiling

(i) Simple boiling.

(ii) Repeated boiling, while changing water.

(d) Wet extraction process for starch

(i) Starch extraction without subsequent gelatinization.

(ii) Starch extraction with subsequent gelatinization.

3. Detoxification by fermentation

(a) Spontaneous fermentation.

(i) Fermentation followed only by washing.

(ii) Fermentation followed by washing and heat treatment (roasting, steaming and drying in hot air).

(b) Fermentation with use of inoculum from earlier preparation (back-slopping) (subdivided as for spontaneous fermentation).

2.3.8 Limitations of cassava utilization

Although cassava is one of the most important root crops growing in tropics including Tanzania, the root protein content is considerably disappointing for being very low in quantity and quality (Collins and Temalilwa, 1981; Okigbo, 1995). It does not provide adequate protein for human requirements even when ingestion exceeds caloric requirements (Badrie & Mellowes, 1992). Thus, it is regarded as inferior food by many consumers and non-consumers and is always blamed as a source of malnutrition particularly in areas where it was consumed and adopted into foods without nutritional enrichment (Collins and Temalilwa, 1981; Hahn *et al.*, 1986). The incidence of malnutrition is especially high among children subsisting on cassava-based diets (Collins and Temalilwa, 1981).

There was a delay on integrating the root into food systems in many societies due to its high cyanide content, which requires detoxification before being consumed (Okigbo, 1986). The integration of cassava product into traditional weaning food formulations may be limited by its high viscosity and tasteless characteristics, which require some modification prior to blending. The consumption at family level and processing unit is limited on the use of fresh roots due to its rapid deterioration if kept for more than two or three days after harvesting (Onwueme 1979; Kapinga *et al.*, 1998,). As a result uneconomical piece meal harvesting has to go even during dry season when the ground is hard and digging is tedious (Onwueme, 1982).

2.4 Soybean

2.4.1 Overview

Cassava does not provide adequate protein for human requirements even when ingestion exceeds caloric requirements. However, soybean (*Glycine max*), an abundant and economical source of protein can be used to increase protein content and to improve the quality of cassava flour-based diets (Badrie and Mellowes, 1992). Its addition to a mixed diet, it greatly improves the quality of the diet's protein (Waingartner, 1987; Badrie and Mellowes, 1992). Soybean is native to eastern Asia. It was reported to be grown as early as 2800 B.C. in China and was considered as one of five sacred grains. By 19th century soybeans were planted in Europe. They were introduced to Africa via Nigeria since early last century and Zimbabwe since early 1920s. Currently, there are more than 150 varieties. The yellow soybeans are the dominant class used in the market. Other minor classes include green, brown and black varieties (Waingartner, 1987).

2.4.2 Soybeans as a world major protein source legume

Soybeans being high in protein content and rich source of edible vegetable oil are considered as important crop throughout the world. In Africa, there are about eleven countries having interest to varying degrees in soybean planting. Zimbabwe, Zaire, Zambia and Nigeria have official interest extended to utilization aspects and there are ready outlets for utilization at both commercial and community level (Weingartner *et al.*, 1987). Although native to Eastern Asia, a bulk of soybean is produced in the United States followed by Brazil, Argentina and China. While USA produces more than 50 % of the world soybean, Brazil, Argentina and Paraguay account for approximately one third of global soybean production and place them among the leading exporting countries (Skorburg, 2001).

2.4.3 Importance of soybeans

Soybean provides as much or more protein calories than animal products (Damardjati *et al.*, 1996). Its protein content on dry basis is higher than that of meat, fish and eggs (Khan, 1987 cited by Al-Kanhal *et al.*, 1998). It is often used as supplement in different forms of extruded cereal mixture for the purpose of increasing protein content and improving the quality of the blend (Badrie and Mellowes, 1992). Soy protein source is apparently inexpensive and cheaper than animal protein sources (Myaka, 1990; Damardjati *et al.*, 1996). It contains all the essential amino acids (Table 6) and an excellent to be used to fortify cassava flour (Badrie and Mellowes, 1992). However, it has minimum amount of the sulphur containing amino acids, methionine and cystine but high levels of lysine that is the worldwide most limiting amino acid in most low cost diets (Waingartner, 1987; Carrao and Gontijo, 1994). It is also a good source of tryptophan and threonine, the essential amino acids that are also limiting in most low cost diets (Wangairtner, 1987; Sarwar *et al.*, 1993). Whole soybean has good balance of amino acids and an excellent source of calories, minerals and vitamins as indicated in Table 6 (FAO, 1985). In infant formula, soy isolate fortified with methionine was at least satisfactory as protein from cow's milk. Unlike groundnuts, which are commonly used as protein supplement in weaning foods, aflatoxin is not considered as amajor problem in soy storage (Waingartner, 1987). However, if soybeans are improperly harvested or stored they may be contaminated with mycotoxigenic mould like other legumes (Steinkraus, 1994). *But Rhizopus oligosporus* a mould used in the preparation of *tempe* was reported to inhibit the growth of *Aspergilus flavus* and *Aspergilus paraciticus* and also aflatoxin production (Thawboripat *et al.*, 1996) enhancing the safety of fermented soy products through biological control.

Table 6: Nutrient composition of soybean: energy (kcal/100g), macronutrients (g/100g) minerals and amino acids (mg/100g) and vitamins (μg/100g)

Nutrients	Content	Nutrients	Content
Energy	322.0	**Vitamins**	
Water (%)	8.5	Carotene	380.0
Protein (%)	33.7	Vitamin E	1500.0
Lipids (%)	18.1	Vitamin K	190.0
(i) Palmitic acid (mg)	1580.0	Vitamin B1	990.0
(ii) Stearic acid (mg)	590.0	Vitamini B2	520.0
(iii) Oleic acid (mg)	3790.0	Nicotinamide	2510.0
(iv) Linolic acid (mg)	8650.0	Pantothenic acid	1920.0
(v) Linoleic acid (mg)	1000.0	Vitamin B6	1190.0
Carbohydrate	6.1	Biotin	60.0
(i) Glucose (mg)	5.0	Folic acid	230.0
(ii) Sucrose (mg)	6100.0	**Protein fraction**	
Mineral ash	4.7	**Proteins in Total Protein (%)**	
Minerals		Sedimentation fractions	
Sodium	4.0	2S	20.0
Potassium	1740.0	7S (include beta-conglycinin 50% cytochrome Cbeta-amylase lipoxgenase, hemagglutinins)	33.0
Magnesium	245.0	11S	33.0
Calcium	255.0	15S	10.0
Manganese	3.0	**Soluble fractions**	
Iron	8.6	Globulines (salt-soluble)	90.0
Copper	0.11	Albumines (water-soluble)	10.0
Zinc	1.0	**Water soluble fraction**	
Phosphorous	590.0	Glycinin (in 11S) and beta-coglycinin (in 7S)	>70.0
Chloride	7.0	Trypisn inhibitors (in 2S)	15.0
Iodine	0.006	Soybean vascular protein P 34 (gly m Bd 30K) (in 7S)	2.0-3.0
Selenium	0.06	**60%-ethanol-solube fraction**	
Amino acids		Hydrophobic protein (gly m 1.010) (mg/100)	~20.0
Arginine	2360.0		
Histidine	830.0		
Isoleusine	1780.0		
Leucine	2840.0		
Lysine	1900.0		
Methionine	580.0		
Phenylalanine	1970.0		
Threonine	1490.0		
Trptophan	450.0		
Tyrosine	1250.0		
Valine	1760.0		

Source: Stuttgart (1991).

2.4.4 Soybean processing

The objectionable flavours and aroma need to be eliminated or reduced for the purpose of developing new foods based on soy protein or continue using soy protein as additives (Lecomte *et al.,* 1993). Soybean is the major oilseed of the world and rich source of proteins. However, it is associated with antinutritional factors such as trypsin inhibitors and haemagglutinins, among others (Liener, 1953 cited by Ramamani *et al.*, 1996). Industrial processes are designed to improve the food value of soybean by inactivating antinutritional factors and enhancing availability of nutrients (Carrao and Gontijo, 1994). Soybean is usually not consumed directly, but processed into a large number of varieties of popular products (Damardjati *et al.*, 1996). Raw soybean does not promote growth due to the presence of antinutritional factors. However, soaking and cooking under pressure makes soybean a very nutritious source of protein (Kakade and Liener, 1957 cited by Ramamani *et al.*, 1996). But, under this mode of processing, soybean still is associated with raw bean flavour (Ramamani *et al.*, 1996).

Soybean is most popular in far-East and its most popular products are *tempe* (fermented soybean) *tahu* or *tofu* (soybean curd), *taoge* (soybean sprouts), soy sauce, *tauco* fermented mixture *oncom* and *tofu* by products which are consumed as side dishes with rice. Other less popular soybean products are *yuba* soymilk and *sere* (in Indonesia). The processing of soybean improves the nutritional quality of the grain (Damardjati *et al.*, 1996).

2.4.4.1 Soaking

Soaking the soybeans in water was reported to result in elimination of haemagglutinating activity, significant reduction in tannins and trypsin inhibitory activity and improvement of in vitro protein digestibility (Sathe and Salunkhe, 1981). It induces the leaching-out of water- soluble antinutritional factors. Glycosides, alkaloids, phytates, oligossccharides and tannins are all significantly reduced (Kadam and Salunkhe, 1985). De Lumen and Salamat (1980) found that the heat treatment resistant-trypsin-inhibitory activity was accountable by the tannins (polyphenolic compounds) content of the beans and suggested that tannins may also be responsible for trypsin inhibitory activity. During soaking tannin tends to leach out as a result of hydration effect and therefore reduces or removes the effect of heat treatment resistance of trypsin inhibitory activity. However, during soaking there is also leaching out of non-lipid water-soluble nutrient components (Kiers, 2001).

2.4.4.2 Dehulling/decortication

Apart from removing the unwanted part of raw materials of the beans, dehulling significantly reduces alkaloids, tannins and other polyphenols in pigmented seeds. Alkaloids are not only irritant but also induce allergies in infants. Tannins have a significant negative effect on the availability of limiting amino acids such as lysine. However, the removal of alcurone layer of the seed bran eliminates significant levels of phytates, which bind calcium and other divalent cation minerals. For the infant formula dehulling reduces the total levels of indigestible fibres so that infants are able to handle legumes earlier in their diets (Kadam and Salunkhe, 1985).

2.4.4.3 Heat processing

Heat processing improves the quality of product nutritionally, functionally and organolleptically. Simple roasting is a good heat processing method to prepare ready to eat products. In some foods the ingredients are roasted for enhancement of flavour, to inactivate antinutritional inhibitors and improve the protein digestibility. Soybean being associated with antinutritional factors such as trypsin inhibitors and haemagglutinins in addition to others, heat treatment inactivates these antinutritional factors and improves protein digestibility of the products (Ramamani *et al.*, 1996).

The inhibitors are comprised of a complex mixture of proteins, which can be classified broadly into two main groups. One group, of which the Kunitz soybean trypsin inhibitor (SBTI) is the best-known example, has molecular weight in the range of 2000-25000 daltons and it is relatively heat labile. The other group is the Bowman-Birk inhibitor (BBI). It consists of protein family having a molecular weight of 8000 daltons. Because of their high cystine content are generally considered to be relatively heat stable. BBI is unique in that it inhibits chymotrypsin as well as trypsin at two independent binding sites (Liener and Tomlison, 1981).

Ramamani *et al.* (1996) found that roasted soybean was free from trypsin inhibitor activity up to a level of an average of 95±2 %. Haemagglutinins were found to be more heat labile and roasting at 115°C for 10-15 minutes could inactivate 98-100 %. Non-enzymatic browning (a reaction between lysine and reducing sugars) during roasting resulted in low retention of available lysine (59 %) and low enzymatic digestibility (24.7 %) of the proteins. Thus the beneficial effect of longer duration of roasting (15 min.) had on reducing trypsin inhibitor activity, might have been imbalanced by reduction in available lysine and digestibility of the proteins (Ramamani *et al.*, 1996).

2.4.4.4 Fermentation

Non-salted fermented soybean finds their origin in Asia, the nalto triangle region that is Nepal and India, China, Japan and Indonesia (Astuti *et al.*, 2000). In Indonesia, ***Rhizopus*** species are used to ferment soybeans, whereas in Japan, China and Nepal, ***Bacillus*** species are commonly used. An important function of the microorganisms in the fermentation process is the synthesis of enzymes that hydrolyse soybean constituents and contribute to the development of desirable texture, flavour and aroma of the product (Hachmeister and

Fung, 1993). Enzymatic hydrolysis may also decrease or eliminate antinutritional constituents. Consequently, the nutritional quality of the fermented product may be improved (Kiers, 2001).

(a) *Tempe*

Tempe is a traditional Indonesian fermented food made from dehulled, soaked and cooked soybeans inoculated with moulds, particularly *Rhizopus* species e.g. *R. oligosporus*, *R. oryzae*, etc (Kiers, 2001). Fresh *tempe* is a compact mass of cooked soybeans covered, penetrated and held together by dense non-sporulated mycelium of *Rhizopus* species (Damardjati *et al.*, 1996). The major desirable aspects of *tempe* are its attractive flavour, texture and certain nutritional and observed therapeutic properties (Kiers, 2001). In Indonesia, *tempe* is consumed as protein-rich meat substitute analogue, major source of calories and vitamins in the diet by all socio-economic groups (Damardjati *et al.*, 1996). Using local substrates e.g. millet, *tempe* has also been nutritionally evaluated and tested for acceptability in Tanzania (Mugula and Lyimo, 1999).

(b) Benefits of fermented soybean

Primary benefits of soybean fermentation are improvement of organoleptic quality and nutritional value rather than preservation. Consecutive stages of the *tempe* fermentation process such as soaking, leaching and enzymatic modification may result in the removal of bean flavours (Nout and Rombout, 1990). Development of flavours and aroma through fermentation is major characteristic of fermented soybean foods (Steinkraus, 1996). Texture dramatically changes during fungal fermentation leading to cake-like product with meat-like texture (Damardjati *et al.*, 1996).

Many antinutritional factors that are pesent in raw soybeans are leached out or destroyed during soaking and cooking of the soybeans (Nout and Rombout, 1990) but also during fermentation several like phytates may be reduced by 50 % (Damardjati *et al.*, 1996; Tawali *et al.*, 1998). Microorganisms have been shown to break down flatulence causing non-digestible oligosaccharides, such as stachyose and verbascose (Sarkar *et al.*, 1997). Soybean fermentation has shown to improve the bioavailability of dietary zinc and iron (Kasaoka *et al.*, 1997; Hirabayash *et al.*, 1998) and can have significant effects on the synthesis of vitamins e.g. B_{12} (cyanocobalamin) potential for dietary management of anaemia (Bisping *et al.*, 1993; Denter *et al.*, 1998).

Fermented soybean products have been shown to inhibit enterotoxigenic *E. coli* (ETEC) infection in rabbit to reduce fluid losses and were reported to be beneficial in terms of shorter duration of diarrhoea episodes as well as rehabilitation period in malnourished children (Kiers, 2001). *Tempe* is a good source of vitamins such as thiamin, riboflavin, pyridoxine, folic acid, niacin, biotin, pantothenic acid and vitamin B_6, rich sources of B_{12} for vegetarians and minerals such as calcium, phosphorus and iron (Damardjati *et al.*, 1996). Fermented soybean contains high soluble fibre that can decrease blood glucose and it also contains antibiotic qualities (Damardjati *et al.*, 1996). It has been reported by Damardjati *et al.* (1996) that *tempe* has hypocholesterolamic properties, antioxidant effect and may be used for dietary management of degenerative (ageing) diseases, underscoring its importance in the human diets.

2.4.4.5 Germination

The process of germination of cereals and legumes involves complex reactions that break down macromolecules such as starch and proteins into smaller units. As a result these foodstuffs become more digestible. Therefore germination is a useful process in the development of weaning foods due to improved digestibility. Mbithi-Mwikya (2000) reported that there was an increase in lysine and tryptophan during germination due to the nitrogen provided with glutamic acid and proline for the synthesis of lysine and other essential amino acids. However, Bau *et al.* (1997) reported a gradual decrease in the available lysine level and lipid content as germination progressed in soybeans and both total and the non-protein nitrogen increased after five days of germination. Longer time of soaking (12 to 18h) and germination (24 to 48 h) resulted in lower levels of the antinutritional factors. In soaking, hydration tends to decrease the levels of antinutrients by leaching them out (Chau and Cheung, 1997; Muyanja *et al.*, 2003). Seed germination has been reported to reduce the levels of phytates, tannins and trypsin inhibitors (Kataria *et al.*, 1989).

2.4.5 Soybean production and utilization

Soybeans were firstly introduced into Tanzania in 1907 and much effort to grow it in large scale began in 1947. Bossier, (spherical and yellow) is the common variety in Tanzania and the production is restricted to Mtwara, Lindi and Morogoro. It is important in Tanzania as an alternative crop for correcting protein deficiency among the population (Myaka, 1990). Malnourished children in Zaire and Nigeria have used soybean for dietary – management of protein –energy malnutrition. Children including those with kwashiorkor and marasmus consistently seem to thrive and gain weight when fed foods fortified with soybean (Weingartner *et al.*, 1987).

2.4.6 Limitations of soybean utilization

The soybean utilization is limited due to the presence of trypsin inhibitors that are regarded as growth inhibitors because they affect protein digestion (Liener, 1980). Additional to that is the presence of phytic acid, which decreases the availability of divalent cations (e.g. calcium, iron and zinc) by the formation of an insoluble protein-phytic acid mineral complex, hence causing reduced availability of zinc in soybean foods (Edman and Forbes, 1981 cited by Carrao and Gontijo, 1994). The organoleptic characteristic of soy protein supplement is associated with objectionable flavour and aroma (the grassy or bean flavour and bitter and astringent characteristic). The presence of phosphatidylcholine bound to soy protein develops bitter flavours upon oxidation (Kinsella and Damoderan, 1980) while the characteristic bean flavours or aroma are partly derived from the raw materials and partly formed by oxidation of residual fats (Oliver *et al.*, 1981).

2.5 Finger millet

2.5.1 Introduction

Finger millet (*Eleusine coracana*) probably originated in the highlands of Uganda and Ethiopia where farmers have been growing it for thousands of years (Werth *et al.*, 1994). Varadaraj and Horingane (1998) describe the grains as small, only 1-2 mm in diameter, and reddish brown in colour. It is directly ground into flour to make thick pap or allowed to germinate and processed into dumpling-like products, beer or malt. Like cassava, finger millet is a subsistence food crop and its small seeds can be stored safely for many years without insect damage, which makes it a traditional component of farmers' risk avoidance strategies in drought-prone regions of eastern Africa and South Asia. It is highly palatable and excellent source of methionine that was reported to be limited in soybean and other legumes.

2.5.2 Millet as world source of calories and protein

Finger millet provides calorie and protein for millions of people in Africa and Asia. Although millet represents less than 2 percent of world cereal utilization, it is an important staple in a large number of countries in the semi-arid tropics, where low precipitation and poor soils limit the cultivation of other major food crops. World finger millet production is concentrated in Eastern and Southern Africa where the leading producers are Tanzania and Uganda (FAO, 1996). Millet utilization is mostly confined to the developing countries (Table 7). Accurate data are not available for most countries, but it is estimated that about 80% of the world's millet (and over 95 % in Asia and Africa) is used as food, the remainder being divided between feed (7 percent), other uses (seed, beer, etc.,) and waste (Table 7).

Table 7: Millet utilization by type, region and selected countries (000 tons), 1992-94 average

	Direct food	Feed	Other uses	Total	Per capital food (kg/year
Developing countries	**21776.00**	**966.00**	**3767.00**	**26509.00**	**508.00**
Africa	**8673.00**	**187.00**	**2328.00**	**11188.00**	**13.40**
Burkina Faso	683.00	2.00	126.00	811.00	68.52
Chard	217.00	0.00	41.00	258.00	33.73
Ethiopia	108.00	0.00	153.00	260.00	1.97
Mali	658.00	3.00	119.00	781.00	74.63
Niger	1440.00	17.00	259.00	1716.00	162.45
Nigeria	3215.00	100	1155.00	4570.00	3150.00
Senegal	505.00	5.00	83.00	593.00	61.61
Sudan	364.00	20.00	76.00	460.00	14.14
Tanzania	177.00	2.00	53.00	233.00	6.41
Uganda	517.00	20.00	95.00	633.00	25.93
Asia	**13103.00**	**748.00**	**1433.00**	**15284.00**	**4.17**
China	3277.00	327.00	257.00	3861.00	2.74
India	9216.00	283.00	1100.00	10599.00	10.23
Central America and the Caribbean	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
South America	**0.00**	**31.00**	**6.00**	**37.00**	**0.00**
Developed countries	**513.00**	**970.00**	**323**	**1805**	**0.40**
North America	0.00	180.00	0.00	180.00	0.00
Europe	0.00	4.00	1.00	5.00	0.00
CIS*	504.00	736.00	316.00	1555.00	1.74
Oceania	0.00	1.00	0.00	1.00	0.00
WORLD	**22289.00**	**1936.00**	**4090.00**	**28314.00**	**4.00**

Source: FAO (1986).
CIS* = Until 1991, areas of the former USSR.

2.5.3 Importance of finger millet

Millets are able to withstand stress better than most cereal crops, can be grown on poor sandy soils with low water holding capacity and tillage is not a common practice (Badi and Monawar, 1991). It is a high nutritious food especially recommended for children, convalescents and the elderly. It is nutritionally superior to other cereals (FAO, 1996). It is an excellent source of calcium and iron micronutrients (Table 8). Millet utilization is limited due to the presence of antinutrients such as tannins and phytates (Mbithi-Mwikya, 2000). Although its protein is poor compared with other cereals, it was positively supplemented in weaning food formulations in connection to iron and calcium deficiencies and as sources of amino acids other than lysine (FAO, 1995). Millets and sorghum are third in cereal production in Tanzania after maize and rice and commonly used in form of porridge by the children under five years old and lactating women (Mugula and Lyimo, 1999). Like cassava, it is regarded as food security crop in semi-arid regions due to excellent storage qualities, resistance to diseases and tolerance to moisture stress.

Table 8: Mineral composition (mg/100g) of common cereals eaten in East Africa

Cereal	Mineral content		
	P	Ca	Fe
Finger millet	320.0	398.0	3.9
Maize	220.0	16.0	3.6
Rice	125.0	9.0	1.7
Wheat	210.0	36.0	3.6

Source: West *et al.* (1988).

It was reported by Babu *et al.* (1987) that some high protein (8-12%) and high yielding varieties of finger millet were also rich in calcium (294-390mg/100). Therefore, finger millet not only maintains nitrogen balance but also improves calcium retention. Therefore, it could be used to overcome the calcium deficiency when supplemented with other foods.

2.5.4 Limitations of finger millet utilization

Finger millet contains high amount of tannins, catechin equivalents (Ramachandra *et al.*, 1977) and substantial amounts of dietary fibre including phytic acid (Rachie and Peters, 1977; Pore and Magar, 1979 cited by Barbeau and Hillu, 1993). Tannins and dietary fibre may adversely affect the protein digestibility (Ramachandra *et al.*, 1977) and mineral absorption (iron availability) in finger millet based diets (Udayasekhara and Deosthale, 1988). This contributes to the constraint in its utilization and adoption into weaning foods.

Addition to that, there is a limitation due to the presence of cyanide, a toxic factor in germinated millet. A danger of sickness or death from cyanide ingestion must always be borne in mind when germinated finger millet is utilized. Its consumption has been implicated in e tiology o f goitre in rural Sudan due to its poor iodine content (Badi and Monawar, 1991; Obizoba and Atii, 1994). In view of these facts, finger millet was used in malted form as source of calcium and iron.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Cassava preparation

About 12 months fresh cassava roots (*Kibandameno*) were purchased from farmers in Morogoro municipality. The roots were peeled and washed in tap water. The peeled-washed whole roots were soaked in tap water in a ratio of 1:3 (roots: water) and fermented for six days until they became very soft. Fermented soft roots were washed three times with tap water and broken into small pieces by hands for drying. Clean soft roots were sundried to about 10% moisture content. The dry cassava was milled and sieved with 500-micron sieve to reduce total fibre content and kept for weaning food formulation.

3.2 Soybean preparation

Soybean (Bossier variety) was purchased from a farmer at Sokoine University of Agriculture. The beans were sorted to remove extraneous matter and damaged (insect and moisture damaged, immature and broken) beans. The soybeans were divided into five treatments of four kilograms each. Each treatment was processed differently from others after being soaked for 12 h in a ratio of 1: 3 (soybeans:water). Four treatments were soaked in tap water of about 30°C while a treatment for fermentation was soaked in hot (100°C) water and left to cool at ambient temperature overnight.

3.2.1 Soybean processing techniques

Five treatments were applied to the soaked soybeans as summarized in Figure 2.

(i) Treatment I -Fermentation

The seeds of a sample of four kilograms of soybean soaked in boiling water for 12 h, and thereafter were dehulled. The hulls were separated from the seeds by hand and accomplished by flotation with water. The dehulled beans were boiled for 60 min, water drained and beans dried superficially. Superficial dried beans were inoculated with 0.2% w/w *Rhizopus oligosporus* (NRRL 2710) starter culture obtained from the Microbial Genomics and Bioprocessing Research Unit, National center for Agricultural utilization Research, United Stated Department of Agriculture, Illinois, USA. The beans were packed in plastic bags enough to contain 250g each. The plastic bags were perforated with a needle at an interval of about one centimetre from one perforation to another to allow air circulation as fermentation progressed. The beans were incubated for 36 h at room temperature (30°C) in a well-ventilated chamber and over raised racks to allow proper air circulation. During fermentation the fermenting soybean bags were turned up side down periodically to ensure homogeneous distribution of air and removal of excess water that might block the perforations. At about 36 hours of fermentation the soybeans were covered and bound together by white fungal mycelium. The beans were removed from the incubation before sporulation started. The cake-like fermented soybeans were sliced and blanched using steam for 5 min. The fermented and blanched product was solar-dried to about 3.4% moisture content, milled and kept for weaning food formulation.

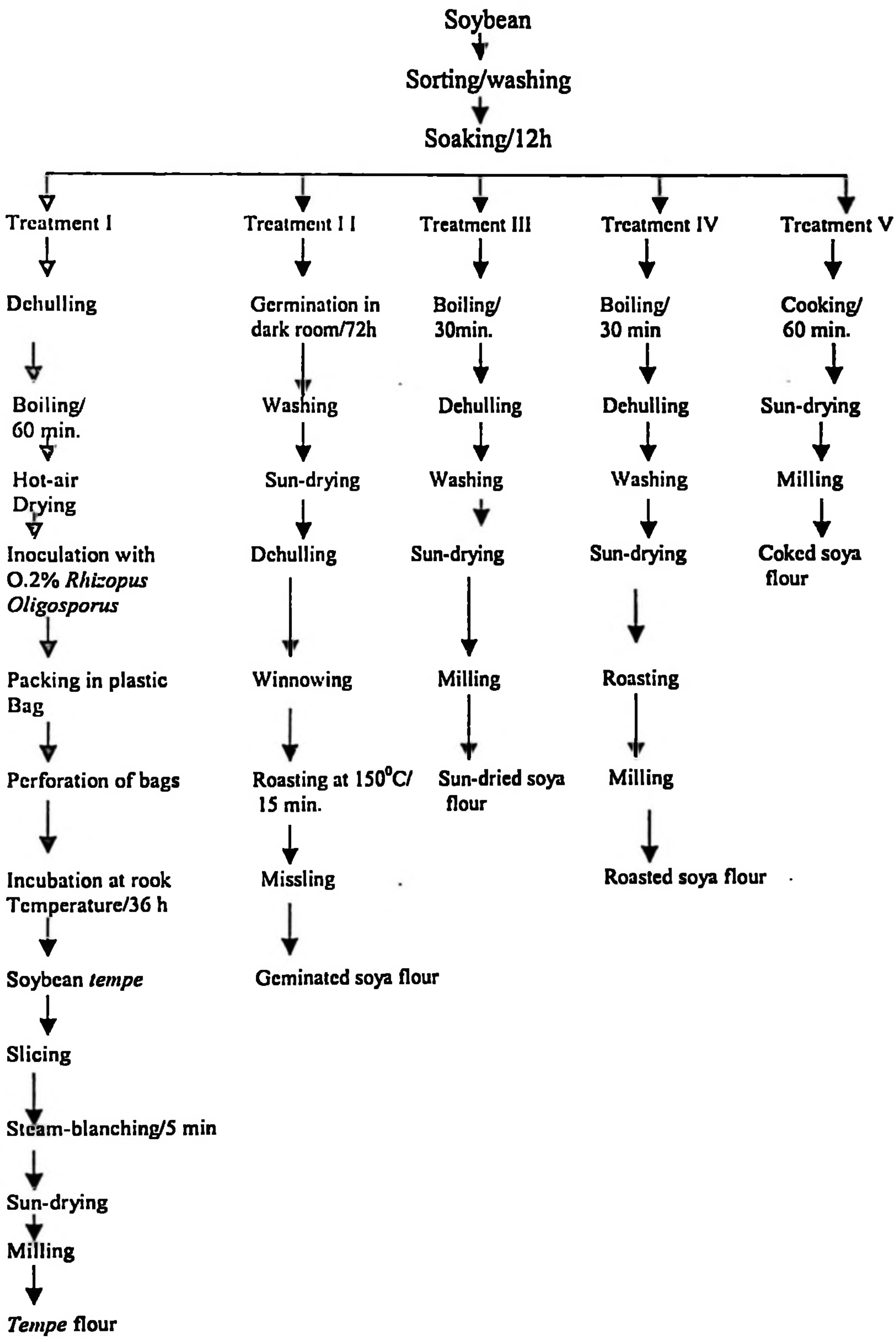

Figure 2: Soybean processing flow diagram.

(ii) Treatment II-Germination

The four kilograms of soaked soybeans were drained for six hours to remove excess water. Drained soybeans were spread on a piece of moistened cotton cloth and covered by another piece of moistened cotton cloth. The process of germination was carried out in a dark place at room temperature (30°C) for 72 h. During germination, checking the germination temperature and state of moisture content in the chamber was applied to monitor the process. When the sprouts reached an average length of 3.4 mm (72 h), the sprouted soybeans were removed from the germination chamber. The sprouted beans were rinsed by distilled water, separated from the ungerminated beans and sun dried to about 10% moisture. Dried soybeans were dehulled by hand and winnowed. The germinated dry soybeans were roasted at 150°C for 15 min, milled and kept for weaning food formulation.

(iii) Treatment III - Sun-drying

Four kilograms of soaked beans in treatment III were boiled for 30 min, dehulled by hand and washed thoroughly to accomplish separation of the beans from the hulls. The dehulled soybeans were sun-dried to about 8% moisture content and milled for blending to produce the weaning foods.

(iv) Treatment IV- Roasting

Four kilograms of soybeans in treatment IV were boiled for 30 min dehulled mechanically by hand, thoroughly washed to accomplish the separation of hulls from the beans and sun-dried to about 8% moisture content. The dried beans were roasted at 150°C for 15 min, milled and kept for blending with other ingredients.

(v) Treatment V-Cooking

Soaked soybeans in treatment V were boiled for 60 min without dehulling, drained and sun-dried to about 10% moisture content, milled and blended for weaning food formulation.

3.3 Finger millet preparation

Finger millet *(Eleusine coracana)* local light brown variety was purchased from Morogoro Municipality central market. The grains were sorted to remove extraneous matter and damaged grains by floatation. The grains were washed thoroughly and soaked for 12 h in ratio of 1:3 grains to water. The grains were spread over a piece of moistened cotton cloth and covered by another moistened piece of cotton cloth. The grains were allowed to germinate in dark chamber at room temperature (30°C) for 36 h to have sprouts of an average length of 4.0 mm. The malted grains were removed and sun-dried to about 10% moisture content. Dried grains were milled and blended with other ingredients for weaning food formulation.

3.4 Formulation of weaning foods

Each soybean treatment was in three different sets of proportions:

(i) 60% cassava, 20% soybean and 20% finger millet

(ii) 50% cassava, 30% soybean and 20% finger millet and

(iii) 50% cassava, 40% soybean and 10% finger millet.

The three proportions for each treatment were evaluated for nutrient content in triplicate.

3.5 Nutritional quality

3.5.1 Proximate composition

The proximate composition (dry matter, crude protein, crude fibre, oil and ash contents) for each ingredient and each formulation were determined according to standard methods of AOAC (1995). The results were presented as an average of triplicate determinations.

3.5.1.1 Dry matter

Dry matter was determined by oven drying method 925.10 (AOAC, 1995). Five grams of the sample were taken for dry matter determination and oven dried at 105°C for 24 h to a constant weight. The sample was dried in pre-dried and pre-weighed crucibles. Dry matter was obtained as the difference between moist sample before drying and dry sample after subjecting to the oven for 24 h. The difference obtained was expressed as percentage dry matter with respect to original amount of the sample taken as follows:

$$\%\text{ Dry matter} = \frac{(C - B) \times 100}{A}$$

Where: A = Weight of the sample taken (g)

B = Weight of dry sample (g)

C = Weight of crucible and dry sample (g)

(C - B) = Weight of dry sample (g).

3.5.1.2 Ash

Mineral ash was determined according to AOAC (1995), method 923.03. One gram of dry sample from dry matter determination was taken for mineral ash determination. The sample was placed into a pre-heated and pre-weighed crucible and incinerated in a muffle furnace at 550°C for 4 h until grey ash was obtained. Total mineral ash was calculated as difference between weight of sample before and after incineration.

$$\% \text{ Mineral ash} = \frac{\text{Weight of as (g) x 100}}{\text{Weight of dry sample (g)}}$$

3.5.1.3 Crude protein

Crude protein was determined by using macro-Kjeldahl method (AOAC, 1995), Official method 920.87. Dried samples (0.25 g) were weighed into digestion tubes. About 10 g of catalyst (mixture of 10 g potassium sulphate, 0.5 g copper sulphate and 1.0 g titanium) was added into each tube with samples. Concentrated sulphuric acid (5ml) was added to each tube and digested using Tecator digestion system 40 (model 1016 digester, Sweden) for 3 h to obtain a clear greenish solution of digest. The digest was cooled and one tube after another was assembled into distillation unit (Foss Tecator, model 2200 Kjeltec auto distilling unit, Sweden). Water (30 ml) was added to the digest followed by 40% sodium hydroxide (30 ml) and steam distilled for 3 minutes. The distillate (150 ml) was collected in 20 ml weak acid (2% boric acid) and titrated against 0.1N standard hydrochloric acid. Blank determination was carried out in the same manner using reagents without sample.

$$\% \text{ Nitrogen was calculated as } \% \text{ N} = \frac{0.0140771 \text{ x (titre - blank)}}{\text{Weight of sample (g)}} \text{ x } 100$$

The protein content was calculated as % Protein = % N x 6.25

3.5.1.4 Crude fibre content

Ankom fibre analyzer (model ANKOM 220, USA) was used to determine crude fibre content as outlined by AOAC (1995) in official method 920. 86. One gram of sample was taken for crude fibre determination. The sample was first digested by dilute acid (0.125M H_2SO_4) for 30 min and washed three times with hot water. The residues were then digested by dilute alkali (0.125M KOH) for another 30 min washed by hot water three times.

Digested residues were dried in the oven for 12 h, cooled and weighed. The residues were then placed in muffle furnace and incinerated at 550°C for 2 h, cooled and weighed again. Total fibre content was taken as difference between residues before and after incineration.

$$\% \text{ Crube fibre} = \frac{W_1(g) - W_2(g) \times 100}{W(g)}$$

where W_1 = Weight of sample residues before incineration (g)

W_2 = Weight of the sample residues after incineration (g)

W = Weight of dry sample taken for determination (g).

3.5.1.5 Crude fat

Total fat was extracted by Soxtec system (HT model 1043-extraction unit AB, Sweden) and the procedure outlined in AOAC (1995) in official method 920.85 was followed. The procedure involved continuous extraction of fat from the sample by light petroleum spirit (40-60°C boiling point range) for eight hours. Petroleum spirit was then evaporated and the weight of the crude fat was determined.

Three grams of the dry sample were used for crude fat determination. The sample was placed into extraction thimble, plugged with cotton wool and assembled to the Soxhlet apparatus. Petroleum ether (100 ml) was used for continuous reflux for eight hours. Petroleum spirit was then evaporated near to dryness. Pre-weighed cups containing fat were dried in the oven at 80°C for 3 h, cooled in a desiccator and weighed.

$$\% \text{ Crude fat} = \frac{\text{Weight of crude fat}(g) \times 100}{\text{Weight of dry sample}(g)}$$

3.5.1.6 Carbohydrate

The carbohydrate content in this study was determined as percentage difference (AOAC, 1995) using the following formula:

% Carbohydrate =100 – (% protein + % crude fibre + % crude fat + % mineral ash)

3.5.1.7 Energy

Energy value for ingredients and formulated products was calculated by multiplying % fat, by factor of 9 and % protein and % carbohydrate by factors of 4 (AOAC, 1990).

3.5.2 Minerals

The ash obtained from the mineral ash determination was used for estimation of individual minerals in the ingredients and in the formulated products. The procedure was the same as outlined in the AOAC (1990). The ash was dissolved in 1:1 HCl and left for 12 h to allow extraction of minerals. The solution was filtered quantitatively into 100 ml volumetric flask. Calcium, iron and zinc were determined using a UNICAM atomic absorption spectrophotometer (Model 919, Cambridge, England). Phosphorus was determined using UV/VIS/NIR spectrophotometer (PYE UNICAM model Pu 8620, Cambridge, England) at 420 nm wavelengths after treated with ammonium vanado-molybdate reagent.

3.5.3 Prediction of Amino acid content, amino acid score, % protein energy and net dietary protein.

3.5.3.1 Amino acid content

Theoretical values (West and Tenalilwa, 1988) for amino acid of the ingredients used in the weaning food formulations were used to estimate amino acid content in the formulations.

3.5.3.2 Percent protein energy

$$\text{Percent protein energy was given as} : \frac{\text{amount of prtein energy in the formulation x 100}}{\text{total energy in the respective formulation}}$$

3.5.3.3 Amino acid score

Amino acid score was estimated according to Pellet and Youny (1980)

$$\text{Amino acid score} = \frac{\text{\% the most limiting amino acid in the test portion}}{\text{\% the same amino acid in FAO/WHO/UNICEF reference pattern}}$$

3.5.3.4 Net dietary protein

Percent net dietary protein calories was predicted from amino acid score and percent protein energy (Calories) using Mosha and Bennink (2004) formula

$$\text{\% NDP calories} = \frac{1.25 \text{ x \% protein energy x amino acid score}}{100 + 0.064 \text{ x \% protein energy x amino acid score}}$$

3.5.4 Toxcic constituent and Antinutritional factors

3.5.4.1 Hydrocyanic acid

Hydrocyanic acid (HCN) in cassava and malted finger millet flour was determined by alkaline titration method outlined in AOAC (1995) official method 915.03 B. Ten grams of the ground sample were placed in Keljedahl tube. Water (75 ml) was added and assembled into distillation unit for distillation while distillate-receiving tube was dipping into a 20 ml solution of sodium hydroxide (0.5 g in 20 ml water). The sample was left connected to the distillation unit to autolyse for two hours. After two hours the sample was steam-distilled and 150 ml of distillate was collected. Collected distillate was brought to 250 ml volume and an aliquot of 100 ml was titrated against 0.02 N $AgNO_3$ using microburet to a faint but permanent turbidity that was recognized against black background.

1ml of 0.02N $AgNO_3$ = 1.08 mg HCN (Ag equivalent to 2 CN).

3.5.4.2 Tannin

Vanillin hydrochloric acid method was used to determine condensed tannin in finger millet and soybean ingredients. Condensed tannin (proanthocyanidins) and leucoanthocyadins (catechins) react with vanillin in the presence of HCl to give a bright red colour that is basis for the calorimetric vanillin- HCl procedure (Hahn *et al.*, 1984 cited by Gomez *et al.*, 1997). Milled sample (0.25 g) was put into two 50 ml Erlenmeyer flasks. The sample was treated with 10 ml of 4% HCl in methanol, closed by parafilm and shaken for 20 min on a wrist-action shaker. The extract was quantitatively transferred into two centrifuge tubes and centrifuged for 10 min at 4500 rpm (3300 xg). The supernatant aliquots were transferred to 50 ml volumetric flasks. Residues in the centrifuge tube were rinsed back into original flasks by using 5 ml of 1% HCl in methanol covered with parafilm, shaken for another 20 min and centrifuged again for 10 min (4500 rpm). Supernatant aliquot was combined with the first one and made to volume with methanol. After mixing, 1 ml of aliquot was pipetted into the corresponding labeled test tube. Slowly, 5 ml of vanillin-HCl reagent (100 ml of 8% HCl in methanol and 100 ml of 1% vanillin in methanol mixed together in a baker - freshly prepared) was added to each of two test tubes of sample extract. Individual sample blank was prepared by adding 5 ml of 4% HCl in methanol to one ml aliquots of the extract pipetted into last two test tubes. Catechin standard solution was prepared by dissolving 1 mg of catechin into 60 ml of methanol in 100 ml volumetric flask and made to volume with methanol. A working standard solutions were prepared from the above stock solution by pipetting 0.01, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8,.0.9 and 1.0 ml into labeled test tubes to catechin concentrations having 10, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 µg ml^{-1}, respectively. The pipetted standard solution was made to 1 ml with methanol before addition of Vanillin-HCl reagent.

Absorbance of standard solutions, sample extract and sample blank were read in the spectrophotometer (Pye UNICAM model Pu 8620 UV/ VIS/ NIR spectrophotometer) at 500 nm within 20 min after adding vanillin-HCl reagent to standard solution and sample extracts. A standard curve of absorbance (y) against catechin concentration (x) was prepared from catechin standard solution readings and the intercept and slope of that curve was established. Sample blank absorbance was subtracted from the sample absorbance and the corrected absorbance value was substituted into the regression equation to find the concentration of the sample.

Regression equation $y = a + bx$ where a = intercept

b = slope of the graph.

The obtained catechin ($\mu g\ ml^{-1}$) was converted to $mg\ ml^{-1}$ and the percentage catechin was calculated as shown in the equation below:

$$\%\,CE = \frac{CC \times VM \times 100}{Vex\ Wt}$$

Where CC = Catechin concentration $mg\ ml^{-1}$

VM = Volume made up (ml) that is 25 ml

VE = Volume of extract (ml) that is 1 ml

Wt = Weight of the sample (mg) that is 250 mg.

The samples were classified as shown in Table 9.

Table 9: Classification of tannin (catechin equivalent)

Tannin group	Tannin level	Range of catechin equivalents (%)
1	None	0.00
1	Low	0.10-0.25
11	Intermediate	0.26-0.99
111	High	1.00 and above

Source: Gomez *et al.* (1997).

3.5.4.3 Phytates

Phytates in soybeans and finger millet flour were determined by ion-exchange method outlined in AOAC (1995) official method No. 986.11. The phytates were extracted from the sample using dilute acid. The extract was mixed with EDTA/NaOH solution and placed on ion-exchange column. Phytates were eluted with 0.7M NaCl solution and wet digested with mixture of c oncentrated H NO_3/H_2SO_4 t o r elease p hosphorus, w hich w as measured colorimetrically. The amount of phosphorus in original sample was calculated as hexaphosphate equivalent.

(i) Phosphate standard curve preparation

Spectrophotometer was adjusted to 640 nm and equilibrated for 30 min before standards reading were taken. Phosphate standard solution 80 µm/ml was prepared by taking accurately 0.350 g dried desiccated potassium acid phosphate (primary standard) into 1000 ml volumetric flask. Distilled water, 500 ml was added followed by 10 ml of 10 N H_2SO_4. The volume was then brought to 1000 ml with distilled water. Phosphate standard solution of 1.0, 3.0 and 5.0 ml was pippeted into 50 ml volumetric flasks. of distilled water, 20 ml was added to the phosphate solution and mixed thoroughly. Molybdate solution (2.0 ml) was added and mixed thoroughly. Sulfonic acid solution (1 ml) was added and mixed thoroughly. The solutions were brought to volume with water and mixed thoroughly. The solutions left to stand for 15 minutes and read in spectrophotometer (Pye Unicam model PU 8620, Cambridge, England) at 640 nm wavelength.

(ii) Phosphate

Two grams of the sample were used for phytates determination. The samples were placed in 125 ml Erlenmeyer flask and 40 ml of 2.4% HCl (20 ml of 2.4% HCl /g sample) was added to the sample. The flasks were covered with parfilm and shaken vigorously for three hours at room temperature (30°C). Columns were prepared as shaking progressed. Water (3 ml) was used to empty mounted columns and then water slurry of 0.5 g chloride resin was poured into the columns. After the formation of resin bed the columns were washed with 15 ml of 0.7 M HCl followed with 15 ml water. The samples were removed from the shaker and filtered with vacuum through whatman No.1 paper. Blank determination was prepared by mixing 1 ml of 2.4 % HCl with 1 ml Na_2EDTA-NaOH reagent, diluted to 25 ml with water and then poured into the column.

Each filtrate (1 ml) was pipetted into 25 ml volumetric flask then 1.0 ml of Na_2EDTA-NaOH reagent was added. The filtrates were diluted to 25 ml with distilled water, mixed and quantitatively transferred to the columns; elute was discarded. The columns were eluted with 15 ml water and then elutes discarded. The columns were then eluted with 15 ml of 0.1M NaCl and elutes discarded. The columns were further eluted with 15 ml of 0.7 M NaCl and elutes were collected in the digestion tubes. H_2SO_4 (0.5 ml) and HNO_3 (3.0 ml) were added into the digestion tubes with 3 glass beads to each tube. The contents in the digestion tubes were digested on Kjeldahl apparatus over medium heat until active boiling ceased and a cloud of thick yellow vapour filled necks of tubes. The contents were heated for 5 more minutes at the same temperature and another 5 min over low temperature.
After tubes had cooled, 10 ml of water was added. The contents were swirled to dissolve salts. The contents were heated on low temperature for 10 min and the solutions let to cool. The contents were quantitatively transferred to 50 ml volumetric flasks. Molybdate solution (2.0 ml) was added to each flask and mixed well. Sulfonic acid reagent (1.0 ml) was then added to each flask and mixed well. The contents were diluted to 50 ml, mixed well, let to stand for 15 min and absorbance was read at 640 nm wavelength.

The phytates in the samples were calculated as:

Phytate (mg/g sample) = "mcan K" x A x20/ (0.282 x 1000)

Where, A= absorbance

" mean K"= standard P (μg)/A/n (standards); phytate = 28.2% P

n = number of standards

3.6 Acceptability

The porridge made from the formulations was assessed for acceptability (sensory evaluation) according to Scaman (2002) first by 36 panelists at the Sokoine University of Agriculture, Department of Food Science and Technology laboratory. The formulations were then provided to 49 panelists from different socio-economic groups at Turiani hospital in Mvomero district in Morogoro for further evaluation of acceptability. Five-point hedonic scale was used for rating the formulations. The parameters assessed were appearance, colour, taste, odour, consistency and overall acceptability. Rating of the parameters was: 5-Like extremely, 4-Like moderately, 3-Neither like nor dislike, 2-Dislike moderately and 1-Dislike extremely.

3.7 Statistical analyses

The samples were analysed in triplicate determinations. The means obtained for sensory evaluation, proximate composition and minerals determinations were subjected to analysis of variance (ANOVA) using MSTAT C statistical programme. The Duncan's Multiple Range Test was used to determine significant differences in between the parameter means.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Nutrient quality of cassava, soybeans and finger millet

4.1.1 Proximate composition

Proximate composition for cassava, soybean and finger millet was evaluated before weaning foods formulation to assess the effect of processing techniques on nutrients content. Raw soybean (Bossier variety) flour and unfermented cassava (Kibandameno variety) flour of the same varieties as those used for weaning food recipe were evaluated as control for soybeans and fermented cassava, respectively. The results for proximate composition of cassava, soybean and finger millet were as shown in Table 10.

Table 10: Proximate composition (%) and energy content (Kcal/100g) of weaning food ingredients (on dry weight basis)

Processing technique	Dry matter	Crude protein	Crude fibre	Crude fat	Total Ash	Carbo-ydrate*	Energy
S-G-R	98.3^a	41.3^c	9.7^c	21.4^d	6.1^a	21.5^d	434.4^e
S-F	96.4^a	46.9^a	6.2^d	28.9^a	3.2^e	15.4^f	$503.8.^a$
S-D-R	96.0^a	45.6^b	9.4^c	28.9^a	3.7^d	12.7^g	492.1^b
S-C	93.8^b	41.0^c	10.4^b	25.5^c	4.8^c	18.8^e	464.5^d
S-D-Dr	93.9^b	46.5^a	9.4^c	27.8^b	3.7^d	12.3^g	485.8^b
F-Ca	90.3^c	1.9^f	2.1^f	0.4^f	0.7^h	94.8^a	390.7^f
M-Fm	90.0^c	9.9^e	3.1^e	0.5^f	1.8^g	84.9^b	384.7^f
U-Ca	90.2^c	1.8^f	1.5^g	0.6^f	2.2^f	93.9^a	387.7^f
Ra- So	93.7^b	37.8^d	11.5^a	19.9^e	5.7^b	37.1^c	476.2^c
LSD ($p<0.05$)	3.9	0.8	0.5	0.9	0.2	0.0	3.9

Values are means of triplicate determinations.

*Determined by difference (100-CP+CF+CFat+Ash).

Key :S = Soaked; G = Germinated; R = Roasted; F = Fermented; D = dehulled; C = Cooked; Dr = Dried; M = malted; Fm = Finger millet; U = Unfermented; Ca = Cassava; Ra = Raw; So = Soybean. Means bearing different superscript letters in the columns are significantly different ($p<0.05$).

4.1.1.1 Dry matter

Dry matter of ingredients ranged between 90.0 and 98.3% (Table 10). Soaked-germinated-roasted soybean had the highest dry matter (98.3%) while the lowest value was in malted finger millet (90.0%). The highest dry matter in soaked-germinated-roasted soybean (98.3%) was not significantly different (p>0.05) from dry matter of soaked-fermented (96.7%) and soaked-dehulled-roasted (96.0%) soybeans. Raw soybean (93.7%) had the lowest dry matter among the soybeans. However, it was not significantly different (p>0.05) from soaked-dehulled-dried (93.9%) and soaked-cooked (93.8%) soybeans. Soaked-fermented cassava (90.2%) was not significantly different (p>0.05) from cassava control (90.3%). Leaching out of water-soluble components and metabolism of carbohydrates during germination contributed low dry matter in malted finger millet (Malleshi and Klopfenstein, 1998). The highest dry matter observed for soaked-germinated-roasted soybeans was probably due to nutrients concentration through drying and roasting of the soybean after germination that eliminated more water from the dried food sample.

4.1.1.2 Crude protein

The crude protein in the ingredients ranged from 1.8% in unfermented cassava to 46.91% in soaked-fermented soybeans (Table 10). Significant difference (p<0.05) was detected among the soybean processing techniques, soaked-fermented treatment being the superior. However, there was no significant difference observed between unfermented cassava (1.8%) and soaked-fermented cassava (1.9%). Soaked-fermented cassava had higher protein content than cassava control by 11.2%. It was probable for the protein to be enriched in fermented cassava by 6 to 8% through fermentation (Okigbo, 1995).

Soaked-fermented soybean (46.9%) was highest in protein content but it was not significantly different ($p>0.05$) from soaked-dehulled-dried soybean (46.5%). The lowest protein content among the processed soybeans was observed in soaked-cooked soybean (41.0%), which was not significantly different ($p>0.05$) from soaked-germinated-roasted soybean. Protein in raw soybean was lower than protein content in the processed soybeans (Table 10). The highest protein content (46.9%) of soaked-fermented soybean was higher by 24.1% than protein content in raw soybean (37.8%). High protein content in the processed soybean was probably due to effect of nutrients concentration as results of leaching out of non- lipid and non-protein water-soluble components. Biomass utilization of other constituents by the mould might cause the apparent increase in crude protein content in soaked-fermented soybean treatment (Matsuso, 1990 cited by Mugula and Lyimo, 1999). However, Sarkar *et al.* (1997) reported a 60-fold increase in amino acid that accounted for approximately 26% of total amino acid content when soybean was fermented with *Bacillus subtilis.* It was further reported that about 19-20% protein in fresh fermented soybeans and more than 50% protein on dry weight basis could be obtained in fermented soybean (Damardjat *et al.*, 1996). Nout and Ngoddy (1997) observed protein solubility and enhancement by 50% through fermentation. Protein may also accumulate during fermentation (Shekib, 1994). The obtained value for soybean control was well compared to 34.3 to 40.7% protein content of different unprocessed varieties of soybeans reported by Saxena *et al.* (1994). The same value was also supported by 37.32% protein content for most of the tropical soybeans (Vasconcelos *et al.*, 1997).

Protein content (46.5%) in soaked-dehulled-dried soybeans was higher than (45.6%) in soaked-dehulled-roasted soybeans. Non-enzymatic browning (a reaction between lysine and reducing sugars) might affect protein content in soaked-dehulled-roasted soybeans during roasting at 150°C for 15 min. Ramamani *et al.* (1996) observed low retention of available lysine (59%) and low enzymatic digestibility due to non-enzymatic browning during soybean roasting. Protein content of soaked-germinated-roasted (41.3%) was lower than that of soaked-dehulled-roasted soybeans (45.6%). Crude protein of both soaked-germinated-roasted and soaked-dehulled-roasted soybeans would apparently increase partly due to loss of water-soluble components during soaking (Lee and Karunanithy, 1990) and would probably decrease due to effect of non-enzymatic reaction (Ramamani *et al.*, 1996). However, during germination nutrients were derived from the embryo mainly for the growing root and shoot and those resulted in loss of proteins (Malleshi and Klopfenstein, 1998). Chandrasiri *et al.* (1987) cited by Bau *et al.* (1997) also reported a rapid decrease in protein level during short germination period (5 days) and increased slightly with continuous growth of soybean seedlings.

4.1.1.3 Crude fibre

Crude fibre was significantly different ($p<0.05$) among the ingredients (Table 10) and among the soybeans in different processing techniques. The values ranged between 1.9 % in cassava control and 11.5% in raw soybean. The fermented cassava contained significantly higher fibre (2.1%) than unfermented cassava (1.5%). The seed hulls might contribute to high fibre content in both raw soybean (11.5%) and soaked-cooked soybean (10.4%). Soaked-fermented soybean had the lowest (6.2%) crude fibre making it superior to other soybean treatments. Soaked-germinated-roasted, soaked-dehulled-roasted and soaked-dehulled-dried soybeans were not significantly different ($p>0.05$) in crude fibre content. It was reported by Chandrasiri *et al.* (1987) cited by Bau *et al.* (1997) that, whole soybean was a good source of dietary fibre, quite rich in hemicellulose and cellulose. Both animal and human trials suggest that soybean hulls in moderate level in the diet had little effect on mineral bioavailability. Thus, high fibre content obtained in soaked-cooked soybean might not have much effect on mineral bioavailability in weaning foods formulation. Low fibre content in soaked-fermented soybean was the effect of fermentation process. During fermentation there was a microbial degradation of fibre content that accounted for the fermented soybeans to be characterized by high soluble fibre as compared to other legumes (Damardjat *et al.*, 1996). Crude fibre was reduced by 9.6% in soaked-cooked soybean to 45.8% in soaked-fermented soybean due to processing techniques in the study.

4.1.1.4 Crude fat

Fat content ranged between 0.4% (soaked-fermented cassava) and 28.9% (soaked-dehulled- roasted soybean) as shown in Table 10. Some of the obtained values differed significantly ($p<0.05$). However, there was no significant difference ($p>0.05$) observed in fat content in unfermented (0.6%) and fermented (0.4%). Cassava. Low fibre content in fermented cassava was probably due to lipid degradation catalyzed by a variety of fungal lipases during fermentation (Reddy and Pierson, 1994).

Soaked-dehulled-roasted soybean gave the highest (28.9%) fat content. The value (28.9%) was not significantly different ($p>0.05$) from that of soaked-fermented (28.3%) soybean. The lowest value (19.3%) was in raw soybean. The obtained value for raw soybean was slightly higher than the reported value for yellow soybeans (17.7%) (Damardjati *et al.*, 1996) but was within fat content of 18.3 to 21.5% reported by Vasconcelos *et al.* (1997). The effect of soybean husks on nutrients content was demonstrated by fat content in soaked and cooked soybeans. According to Kiers (2001), non-lipid water-soluble dry matter loss during soaking and cooking would relatively lead to an increase in crude lipid content. However, it was not the case due to retention of seed hulls that accounted on dry matter content after soaking and cooking. The amount of 25.0% fat in soaked-cooked soybean that was lower than for soaked-dehulled-dried soybean (28.3%) explains dry matter concentration due to the effect of leaching during soaking was relatively lower than the effect of dehulling the soybeans.

Soaked-germinated-roasted soybean had the lowest fat (21.4%) of all the processed soybeans (Table 10). During germination lipid diminishes as germination, progresses. At the end of five days, loss of lipids reached 19.8% compared to ungerminated seeds (Chandrasiri *et al.*, 1989 cited by Bau *et al.*, 1997). Mostafa *et al.* (1987) also found that six days of germination induced a decrease in oil content, acid value, iodine value and total unsaturated fatty acids of soybean oil. The peroxide value and total saturated fatty acids pronouncedly increased. Degradation of reserve lipid and carbohydrate on germination is a process whose essential purpose is to provide the energy required for protein synthesis in plant growth (Chandrasiri *et al.*, 1987 cited by Bau *et al.*, 1997).

Bau *et al.* (1997) observed a gradual decrease in the lipid content as germination progressed as well as reduction in lipase inhibitor activity induced by germination process that lead to lipid degradation. Germination or malting of seeds triggers the enzyme systems of sprouting seeds leading to breakdown of complex macro molecules of lipids into simpler forms that are more easily assimilated (Nout and Ngoddy, 1997).

4.1.1.5 Ash

There was a significant difference ($p<0.05$) in ash content of the ingredients. The values ranged between 0.7% (in soaked-fermented cassava) and 6.1% (in soaked-germinated soybean) as shown in Table 10. Total ash of fermented cassava (0.7%) was significantly ($p<0.05$) different from total ash of unfermented cassava (2.1%). Leaching out of water-soluble micronutrients during extended soaking of roots in water for five days probably contributed to low ash content in soaked-fermented cassava as reported by Nout and Ngoddy (1997). Among the soybeans, ash content in soaked-germinated-roasted soybean was the highest (6.1%). The lowest was reported in soaked-fermented soybean (3.2%). Raw soybean was observed to have (5.7%) ash content lower than that of soaked-germinated-roasted soybean. High ash content in soaked-germinated-roasted soybean was due to nutrients concentration in the dry matter through soaking, dehulling, drying and roasting. Raw soybean was not subjected to possible causes of nutrients losses such as leaching and/or dehulling. Thus, was characterized by high ash concentration. The value 5.7% ash content obtained in raw dried soybean was comparable to values reported by Vasconcelos *et al.* (1997) and Saxena *et al.* (1994) of 5.0% for tropical soybeans and a range of 4.5 to 5.3%, respectively.

4.1.1.6 Carbohydrate

Carbohydrate ranged between 12.8 and 94.8% (Table 10) and was significantly different ($p<0.05$). The highest carbohydrate content (94.8%) was in soaked-fermented cassava and the lowest (12.3%) in soaked-dehulled-dried soybeans. The amount observed in fermented cassava (94.8%) was slightly higher but was not significantly different ($p>0.05$) from cassava control (93.8%). Slightly low carbohydrate content in fermented cassava compared to unfermented cassava, was contributed by fat degradation during fermentation and leaching out of water soluble components during extended soaking of the roots that resulted in low ash content (0.7%) compared to (2.3%) in unfermented cassava. Among the soybean treatments, raw soybean had the highest (37.1%) carbohydrate content while the lowest (12.3%) carbohydrate content was observed in soaked-dehulled-dried soybean. There was no significant difference observed between soaked-dehulled-roasted (12.7%) and soaked-dehulled-dried (12.3%) soybeans ($p>0.05$). The significant difference observed in soybeans was contributed by the factors that affected other nutrients distribution (ash, protein, crude fibre, and fat), either degradation or enrichment due to processing techniques. There was a reduction of carbohydrates in soybeans by a factor between 66.9% and 42.1% due to different processing techniques in the study. High carbohydrate in soaked-germinated soybean might have originated from high concentration of the remaining nutrients due to degradation of fat and protein during germination process.

4.1.1.7 Energy

Energy content ranged from 384.9 kcal/100g in malted finger millet to 503.81 kcal/100g in soaked-fermented soybean (Table 10). The high-energy content in soybeans was contributed by high protein and fat energy. Fat and protein energy were very low in cassava. However, carbohydrate energy was very high in cassava as compared to soybeans.

Of the total 503.8 kcal/100g energy obtained in fermented soybean, protein energy was 37.2% and that of fat was 50.5%. In the lowest energy content (347.3 kcal/100g) in unfermented cassava, protein energy was only 1.5% and that of fat was only 2.0% (Appendix 4a).

4.1.2 Minerals

Mineral content (calcium, iron, phosphorus and zinc) of the cassava, soybean and finger were determined before weaning food formulation and the results were as shown in Table 11.

Table 11: Mineral content (mg/100g) of cassava, soybean and finger millet (on dry matter basis)*

Processing technique (Soybean/cassava)	Mineral content			
	Ca	Fe	P	Zn
Soaked-germinated-roasted soybean	317.2^{b}	7.3^{c}	302.1^{a}	4.1^{ab}
Soaked-fermented soybean	354.6^{a}	8.3^{b}	266.8^{ab}	4.3^{a}
Soaked-dehulled-roasted soybean	316.1^{b}	6.0^{d}	282.0^{ab}	3.9^{ab}
Soaked-cooked soybean	308.6^{b}	6.6^{cd}	290.6^{ab}	3.9^{ab}
Soaked-dehulled-dried soybean	332.1^{ab}	5.9^{d}	279.1^{ab}	3.7^{b}
Fermented cassava	35.6^{e}	2.0^{e}	6.2^{d}	0.9^{d}
Germinated finger millet	241.7^{d}	3.1^{e}	8.5^{c}	1.3^{c}
Unfermented cassava	28.2^{e}	2.1^{e}	22.8^{d}	1.4^{c}
Raw soybean	304.4^{c}	9.8^{a}	276.2^{ab}	4.3^{a}
LSD (P<0.05)	27.1	1.0	24.5	4.6

*Values are means of triplicate determinations.

Means bearing different superscripts within the same column are significantly different (p<0.05).

Although it would not expected that fermentation would alter the mineral content (Steinkraus, 1994), soaked-fermented soybean was slightly highest in calcium, iron and zinc content (Table11). Phosphorus was highest in the soaked-germinated-roasted treatment and lowest in soaked-fermented soybean in the processed soybeans. Raw soybean was the lowest in calcium content (Table 11). The results indicated that there was no significant difference (p>0.05) among the soaked-germinated-roasted, soaked-dehulled-roasted and soaked-dehulled-dried soybeans in the content of calcium (Table 11). Soaked-dehulled-dried soybean treatment was the lowest in iron and zinc content. Both fermented and unfermented cassava did not differ significantly (p>0.05) in calcium, iron and phosphorus. Significant differences were observed in fermented and unfermented cassava in zinc content (Table 11). High amount of calcium and iron contents in soaked-fermented soybean was well supported by Hermana *et al.* (1990) cited by Damardjati *et al.* (1996) that soybean (tempe) was a good source of minerals such as calcium, iron and phosphorus.

4.2 Nutrient content of cassava-soybean-based weaning food formulations

4.2.1 Proximate composition

Nutrients composition of the formulated weaning flour (cassava-soybeans supplemented with finger millet) in three different proportions of: (i) 60% cassava 20% soybean and 20% finger millet (ii) 50% cassava, 30% soybean and 20% finger millet and (iii) 50% cassava, 40% soybean and 10% finger millet basing on soybean processing techniques were determined and the results are as shown in Table 12.

Table 12: Proximate composition of cassava-soybean based weaning formulations supplemented with finger millet (dry weight basis)*

Processing technique	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Crude fat (%)	Ash (%)	Carbo-hydrate (%)	Total Energy (kcal/100g)	Protein energy (%)
S-G-R								
60:20:20	91.7^{cde}	11.6^{fg}	3.2^{hi}	4.9^{i}	2.1^{cd}	78.2^{a}	403.4^{f}	11.5^{f}
50:30:20	92.2^{bcd}	15.7^{d}	4.0^{defg}	6.8^{f}	2.6^{b}	70.2^{d}	406.6^{f}	15.4^{de}
50:40:10	93.5^{a}	18.5^{b}	4.6^{cd}	9.5^{d}	3.1^{a}	63.8^{g}	414.6^{de}	17.8^{b}
S-F								
60:20:20	90.5^{g}	12.4^{e}	2.8^{i}	6.3^{g}	1.4^{g}	76.9^{abc}	414.4^{de}	11.5^{f}
50:30:20	92.1^{bcd}	17.2^{c}	3.5^{gh}	9.2^{d}	1.6^{ef}	68.6^{e}	426.3^{c}	16.1^{c}
50:40:10	92.5^{bc}	21.0^{a}	4.2^{def}	12.3^{ab}	1.9^{d}	61.6^{h}	441.5^{a}	19.1^{a}
S-D-R								
60:20:20	91.6^{def}	12.0^{ef}	3.4^{ghi}	7.2^{f}	1.4g	76.1^{c}	417.5^{d}	11.5^{f}
50:30:20	92.0^{bcd}	16.3^{c}	3.7^{fgh}	9.7^{d}	2.0^{cd}	66.8^{f}	424.3^{d}	16.1^{c}
50:40:10	92.7^{b}	20.6^{a}	5.5^{ab}	12.2^{a}	1.9^{d}	59.9^{i}	434.3d	19.1^{a}
S-C								
60:20:20	90.9^{fg}	11.1^{g}	3.8^{efgh}	5.7^{h}	1.8^{de}	77.8^{ab}	405.4^{f}	10.6^{g}
50:30:20	91.3^{ef}	15.3^{d}	4.6^{cd}	8.2^{e}	2.2^{c}	69.3^{e}	413.7^{de}	14.8^{e}
50:40:10	91.6^{def}	18.3^{b}	6.00^{a}	10.4^{c}	2.5^{b}	62.8^{g}	416.3^{d}	17.6^{b}
S-D-Dr								
60:20:20	91.0^{fg}	12.1^{ef}	3.7^{fgh}	6.3^{g}	1.5^{fg}	76.7^{bc}	412.2^{e}	11.8^{f}
50:30:20	91.2^{efg}	16.6^{c}	4.4^{cde}	9.2^{d}	1.6^{ef}	68.4^{e}	423.5^{c}	15.7^{cd}
50:40:10	92.2^{bcd}	20.7^{a}	5.00^{bc}	11.9^{b}	2.0^{cd}	60.4^{hi}	431.6^{b}	19.2^{a}
LSD ($P<0.05$)	0.7	0.5	0.6	0.5	0.7	1.2	3.9	0.6

*Values are means of triplicate determinations.

Means bearing different superscripts within the same column are significantly different ($p<0.05$).

Key: S = Soaked; G = Germinated; R = Roasted; F = Fermented; D = dehulled; C = Cooked; Dr = Dried.

4.2.1.1 General observations

Significant difference ($p<0.05$) was detected among the formulation proportions (Table 12). The difference was both within the same and among the proportions in different formulations. Soaked-fermented treatments were superior in most of the nutrients in the formulations followed by soaked-dehulled-roasted and soaked-dehulled-dried soybean treatments. On the other hand, soaked-cooked treatments were inferior followed by soaked-germinated-roasted soybean treatments in the formulations. There was no significant difference ($p>0.05$) in crude protein and protein energy content in soaked-fermented, soaked-dehulled-roasted and soaked- dehulled-dried soybean formulations.

4.2.1.2 Dry matter

Dry matter increased slightly with increase of soybean proportions. The lowest dry matter was observed in the soaked-dehulled-dried soybean formulation (60:20:20) and the highest was in the soaked-germinated-roasted soybean formulation (50:40:10) (Table 12).

4.2.1.3 Crude protein

Generally, protein values increased with increase in proportion of soybean and decrease in the proportions of c assava and finger millet in the formulations (Table 12). Formulated weaning foods with 60:20:20 proportions of cassava, soybean and finger millet indicated protein content ranging from 11.1% in soaked-cooked to 12.4% in soaked-fermented soybean formulations (Table 12). This range was below the minimum protein requirements recommended for weaning foods by FAO/WHO/UNICEF (1971), the Protein Advisory Group (PAG) of United Nations (20%) and Tanzania Standard (15.2%). The same range was also below the minimum protein value (14.95%) for weaning foods recommended by the FAO/WHO (1994), Codex Alimentarius Standard. Protein content of various home made and commercial weaning foods of Tanzania (Mosha *et al.*, 2000) were also above 12.4%, the maximum value in the 60:20:20 proportions. This implies that to rely on this formulation as weaning food, the protein levels would need to be increased by a protein-rich source. The level of soybean in the formulations therefore needs to be increased in order to attain the minimum protein levels recommended by the cited official standards. The range between 15.3% protein in soaked-cooked soybean and 17.2% in soaked-fermented soybean obtained in the formulations with 50:30:20 proportions seemed at least suitable for weaning foods formulation. That range satisfied the 14.95 and 15.2% protein minimum requirements specified by the FAO/WHO (1994) and TZS, respectively. However, the range was below the protein minimum requirement recommended by the FAO/WHO/UNICEF (1971) (20%). The maximum protein value (17.2%) in the study was superior to most of home made and commercial weaning foods (Cerealac-1 &-2 and Lactogen-1 & -2) of Tanzania (Table 1) (Mosha *et al.*, 2000). The minimum value in the proportions was superior to most of home-made cereal based weaning foods, but slightly lower than commercial weaning foods (Mosha *et al.*, 2000).

The formulations with 50:40:10 proportions of cassava, soybean and finger millet had protein ranging from 18.3% in soaked-cooked to 21.0% in soaked-fermented soybean formulations (Table 12). Soaked-fermented, soaked-dehulled-roasted and soaked-dehulled-dried soybean formulations had protein content above minimum value (20%) recommended by FAO/WHO/UNICEF (1971) (Table 12). However, the minimum value in the 50:40:10 proportions was above protein minimum value recommended by FAO/WHO (1994) and TZS. These proportions had superior protein content to most of home made and commercial weaning foods of Tanzania (Cerelac-1 &-2 and Lactogen-1) except Lactogen-2 (Mosha *et al.*, 2000).

Proteins are essential components of the diet, needed for survival of animals and humans. Their function is to supply adequate amounts of needed amino acids and thus one of its nutritional qualities in foods depends on content, others being digestion, absorption, and utilization of the amino acids. Maximum complementation of amino acids and protein content of about 20% were targeted to satisfy the minimum protein content of 15% required under the Food and Agriculture Organization (FAO)/World Health Organization (WHO) Codex Alimentarius Standard.

Protein quality in terms of amino acid content of the formulated weaning foods basing on the three proportions were predicted using available theoretical values for amino acids of the ingredients used in the formulations as shown in Table 13. Calculated values were compared to the FAO/WHO/UNICEF (1971) reference pattern indicated for children below five years old.

Threonine was the most limiting amino acid basing on the theoretical values shown in Table13. Predicted amino acid profile in the three proportions was below the minimum values recommended by FAO/WHO/UNICEF (1971) pattern for children under five years old. This suggests the need for amino acid composition evaluation before and after the formulations.

Table 13: Predicted amino acid content (g/16g N), amino acid score, protein energy and (%) and NDP calories (%) in the weaning food formulation proportions

Amino acid	Predicted value (g/16g N)			FAO/WHO
	60:20:20	50:30:20	50:40:10	Pattern (2-5yrs)
Isoleucine	1.0	1.2	1.8	2.8
Leucine	1.6	2.2	2.8	6.6
Lysine	1.2	1.8	2.2	5.8
Methionine*	1.4	1.8	2.2	2.5
Tyrosine•	1.0	1.8	1.8	6.3
Threonine	0.6	1.0	1.2	3.4
Valine	1.6	1.4	2.6	3.5
Tryptophan	1.0	1.2	1.6	1.1
Amino acid score (%)	60.0	75.9	69.8	3.4
[1]Protein energy (%)	11.1	15.4	7.4	22.2
[2]NDP calories (%)	5.8	8.4	4.9	0.9

Source: Pellett and Youny (1980), Vasconcelos et al.(1997), West and Temalilwa (1988); Mosha and Bennink (2004).

*Combined value for methionine plus cysteine.

•Combined value for tyrosine plus phenylalanine.

[1]Protein calories (%) was calculated basing on the data abtained from raw soybean, unfermented cassava and malted finger millet in the study.

[2]NDP = Predicted net dietary protein from protein score and %protein calories.

The superiority of the soybean processing in the formulations will then be established basing on the protein quality in terms of amino acid rather than the quantity obtained. From this study, where the ingredients are available 50:40:10 formulations that was probably have high limiting amino acids (Table 13) would seem more appropriate than the other formulations.

4.2.1.4 Crude fibre

Crude fibre in the study was observed to increase as soybean proportions increased. The amount of crude fibre content in 60:20:20 proportions ranged from 2.8% in soaked-fermented to 3.8% in soaked-cooked soybean formulations. The values in these proportions were higher than the maximum requirement (2.2%) specified in TZS and values (1.00 to 1.5%) reported by Mosha *et al.* (2000) for Tanzania commercial weaning foods (Lactogen-1 & -2 and Cerealac-1 &-2). The formulations with 50:30:20 proportions had higher crude fibre content, ranging from 3.5% in soaked-fermented to 4.7% in soaked-cooked soybean formulations. The highest crude fibre content was in 50:40:10 proportions with thc values ranging from 4.2% in soaked-fermented to 5.9% in soaked-cooked soybean formulations. It was earlier reported that whole soybean was a good source of dietary fibre, quite rich in hemicellulose and cellulose. Both animal and human trials suggest that soybean hulls in moderate level in the diet had little effect on mineral bioavailability (Chandrasiri *et al.*, 1987 cited by Bau *et al.*, 1997). Thus, high fibre content obtained in the study might not have much effect on mineral bioavailability in cassava-soybean based weaning food formulations.

4.2.1.5 Crude fat

In terms of fat content, compliance with FAO/WHO/UNICEF (1971) recommended standards (max 10%) both the 60:20:20 and 50:30:20 formulations would seem appropriate. The compliance with TZS (8.25%) only 60:20:20 could apply and the 50:30:20 only for those samples with fat content not exceeding 8.25% (Table 12). With the exception to soaked-germinated-roasted soybean, the 50:40:10 samples were above the FAO/WHO/UNICEF (1971) maximum value (10%). Therefore, such formulations would be rejects. However, all the obtained values for fat content were below the minimum value specified by the FAO/WHO (1994). (14.52 - 41.13%). Fat content increased with increase in soybean proportions in the formulations. This can be explained by the high fat content in the soybean formulations (Table 12). Means for crude fat in the formulations with

60:20:20 cassava, soybean and finger millet were between 4.9% in soaked-germinated-roasted soybean and 7.2% in soaked-dehulled-roasted soybean (Table 12). The values were below maximum value specified by FAO/WHO/UNICEF (1971) (10%) and Tanzania standard (8.15%). The formulations with 50:30:20 proportions contained fat in the range of 6.8% in soaked-germinated-roasted to 9.7% in soaked-dehulled-roasted soybean formulations. The maximum value in the formulations was 19.0% higher than maximum value in Tanzania standard but lower than FAO/WHO/UNICEF (1971) value by 3%. The proportions of 50:40:10 had fat content ranging between 9.5% in soaked germinated-roasted and 12.2% in soaked-dehulled-roasted soybean formulations (Table 12). The amount of fat in the 50:40:10 proportions were too high to have good keeping effect under the tropical conditions. However, for short-term use the high fat levels could be tolerable.

4.2.1.6 Ash

Ash content in the study was below the maximum limit (5% and 5.43%) recommended by FAO/WHO/UNICEF (1971) and TZS, respectively. Ash content was generally increased with increase of soybean proportions. There was an improvement of ash content in the 50:40:10 formulations with a range mean values of 1.9% in soaked-dehulled- dried and soaked-fermented soybean formulations to 3.1% in soaked-germinated-roasted soybean formulations. The small amount of ash content obtained in the formulations suggests the necessity of mineral fortification in the formulations.

4.1.2.7 Carbohydrate

Carbohydrate in the study generally decreased with decrease of cassava proportions in the formulations. The minimum value (59.9%) was obtained in soaked-dehulled-roasted (50:40:10) formulation while the maximum value (78.2%) was in soaked-germinated-roasted (60:20:20) formulation. The values in all proportions were above the minimum value specified by FAO/WHO (1994) (41.13%) and TZS (48.90%). However, a range of 76.2 to 78.2% in the 60:20:20 formulations were above the maximum limit (73.9%) specified by the FAO/WHO (1994) (Table 12). The values were also higher than some of the home made weaning foods (18.42, 19.80 and 60.31%) reported by Mosha *et al.*, (2000).

4.1.2.8 Energy

The highest source of energy was found in the 50:40:10, formulations containing the highest proportion of soybean, as expected the high energy density was derived from the high proportion of soybean (rich in fat) inclusion in the formulation. The energy range of 403.4 kcal/100g in soaked-germinated-roasted to 417.5 kcal/100g in soaked- fermented soybean was obtained in 60:20:20 proportions. Other formulations contained energy of 406.6 to 426.3 kcal/100g and 414.6 to 441.5 kcal/100g in respect to 50:30:20 and 50:40:10 formulations of the soaked-germinated-roasted and soaked-fermented soybeans, respectively (Table 12).

The values in the formulations were generally lower than those in the FAO/WHO (1994) (483.90 to 685.50 kcal/100g) (Table 1). However, all the values in the formulations were above the minimum limits recommended by FAO/WHO/UNICEF (1971) (>360 kcal/100g). Home made and commercial weaning foods were reported to contain 382.34 to 457.09 kcal/100g and 419.24 to 509.91 kcal/100g, respectively (Mosha *et al.*, 2000). The obtained values in the formulations were generally lower than some of the home made and commercial weaning foods. However, the minimum value in the 60:20:20 was above minimum value reported in home-made weaning foods (Mosha *et al.*, 2000).

Low energy distribution in the formulations was probably contributed by imbalances of nutrients d istribution in the ingredients used. While pure cassava could contain only an average energy of 0.7% from fat and 1.7% from protein, finger millet had 1.2 and 8.9% from fat and protein, respectively. On the other hand soybeans had an average of 53.3 and 39.8% from fat and protein energy, respectively (Appendix 2a). Low average energy from fat and protein in cassava and finger millet contributed to low energy density in the formulations. Khan *et al.* (1989) cited by Mosha *et al.* (2000) reported that the imbalance of energy from nutrients affects the overall energy quality of the diet.

The findings reported in the study compared well with the findings reported by other researchers. A research conducted by Mahmud *et al.* (1987) showed that formulation of food mixture in the ratio of 70: 30 cassava and soybean to contain 11.7% protein, 7.3% fat and 407 kcal/100g total energy. The formulation of the same ratios with fermented soybean (tempe) contained 16.2% protein, 12.0% fat and 429-kcal/100g energy. For a diet containing 80-85% cassava and 20-25% soybean, the protein would be around 10.1-10.5 (Collins and Temalilwa, 1981; Numfor and Noubi, 1995). The lipids and energy would be 3.9% and 408 kcal/100g, respectively (Numfor and Noubi, 1995). Diets with 50:30 cassava to cowpeas with sesame and either plantain or squash or pumpkin had a better nutrient composition with protein value above 12 g/100g (Saidu *et al.*, 2003). Increase of protein from reported value of 16.2% in fermented soybean in the formulations with 50:30 cassava and s oybean t o 1 7.2% i n the s tudy w as p robably contributed by the protein component from 20% finger millet. Protein content of finger millet although higher than that of cassava is quite low compared to soybean. Therefore, the increase to that level was dictated by finger millet proportion in the inclusion.

4.2.2 Minerals

Results for minerals (calcium, phosphorus, iron and zinc) in dry weight basis were as shown in Table 14.

Table 14: Mineral composition (mg/100g) of processed cassava-soybean weaning food formulations (on dry weight basis)*

Soybean processing technique	Calcium	Iron	Phosphorus	Zinc
S-G-R				
60:20:20	121.3^{c}	4.0^{bcde}	213.5^{efg}	1.5^{ef}
50:30:20	142.3^{b}	4.2^{bcde}	202.6^{fg}	1.7^{cdef}
50:40:10	143.3^{b}	4.6^{abc}	267.6^{bc}	2.0^{bcd}
S-F				
60:20:20	116.7^{c}	3.6^{ef}	184.9^{h}	1.4^{ef}
50:30:20	146.3^{b}	4.7^{abcd}	207.1^{fg}	1.6^{cdef}
50:40:10	162.3^{a}	4.9^{a}	279.6^{c}	2.2^{ab}
S- D-R				
60:20:20	118.3^{c}	3.3^{f}	217.3^{ef}	1.3^{f}
50:30:20	145.0^{b}	3.8^{def}	$297.1b^{c}$	1.8^{bcde}
50:40:10	160.3^{a}	4.5^{ab}	299.1^{ab}	2.0^{bc}
S-C				
60:20:20	118.0^{c}	$3.^{4ef}$	299.1^{a}	1.3^{f}
50:30:20	141.3^{b}	3.9^{cdef}	227.5^{e}	1.5^{def}
50:40:10	144.3^{b}	4.3^{abcd}	288.7^{bc}	1.9^{bcde}
S-D-Dr				
60:20:20	119.0^{c}	3.4^{ef}	202.4^{g}	1.3^{f}
50:30:20	136.0^{b}	3.6^{f}	257.6^{d}	1.3^{f}
50:40:10	163.7^{a}	$3.8d^{ef}$	286.3^{bc}	2.5^{a}
LSD (0.05)	13.7	0.6	14.5	4.2

*Values are means of triplicate determinations.

Means bearing different superscripts within the same column are significantly different ($p<0.05$).

Key: Ratios are for cassava:soybean:finger millet.

S = Soaked; G = Germinated; R = Roasted; F = Fermented; D = dehulled;

C = Cooked; Dr = Dried.

The effect of small amount of finger millet supplemented in the weaning was not much effective as the amount of soybean proportion in the products. There was an increase of analyzed minerals (calcium, iron, phosphorus and zinc) with increase in soybean proportion. In the proportions with 10 and 40% finger millet and soybean, respectively, mineral contents were higher than the proportions with 20 and 30% finger millet and soybean, respectively (Table 13). It is again quite evident that the increase in proportion of soybean in the formulation besides elevating the proportion of protein, energy and fat also increases the amounts of calcium, iron, phosphorus and zinc. Again, this demonstrates further the advantages of including soybeans in weaning food formulations especially in places where milk is a problem to supply the calcium and where iron sources are a problem to afford. The same advantages apply to resource-poor households where the price of milk is unaffordable.

4.3 Sensory evaluation

A total of 15 samples of weaning foods were formulated basing on different proportions of cassava and finger millet using soybean treated in five different processing techniques. Panelists evaluated each soybean treatment in three sets of different proportions for the purpose of establishing the proportion that would be acceptable. Porridge prepared from the 15 samples was presented for sensory evaluation to 36 semi-trained panelists, comprising of female and male students in the Department of Food Science and Technology at the Sokoine University of Agriculture. Mean scores for appearance, colour, odour, taste, consistency and overall acceptability basing on five point hedonic scale were as shown in Table 15.

Table 15: Mean scores of sensory characteristics of porridges of formulated flour at Sokoine University of Agriculture

Sample/proportion	Characteristic mean scores					
	Appearance	Colour	Odour	Taste	Consistency	Overall acceptability
S-G-R (60:20:20)	3.08^{c}	3.31^{a}	3.11^{b}	2.86^{c}	2.97^{c}	3.00^{a}
S-F (60:20:20)	3.39^{b}	3.36^{a}	3.08^{c}	2.53^{d}	3.25^{c}	3.14^{c}
S-D-R (60:20:20)	3.09^{c}	3.25^{a}	3.28^{a}	3.06^{a}	3.00^{c}	3.28^{c}
S-C (60:20:20)	3.53^{a}	3.56^{a}	3.53^{a}	3.28^{a}	3.19^{c}	3.61^{a}
S-D-Dr (60:20:20)	3.22^{c}	3.25^{a}	3.58^{a}	3.17^{a}	2.97^{c}	3.36^{a}
S-G-R (50:30:20)	3.00^{d}	3.11^{a}	2.72^{b}	2.78^{c}	3.78^{a}	2.97^{c}
S-F (50:30:20)	3.33^{b}	3.31^{a}	2.94^{b}	2.17^{f}	3.36^{b}	3.11^{c}
S-D-R (50:40:10)	3.72^{a}	3.61^{a}	3.47^{a}	3.42^{a}	3.42^{b}	3.72^{a}
S-D-R (50:30:20)	3.36^{b}	3.42^{a}	3.44^{a}	3.17^{a}	3.11^{c}	3.44^{a}
S-C (50:30:20)	2.83^{e}	3.11^{a}	3.39^{a}	3.08^{a}	2.78^{d}	3.25^{b}
S-D-Dr (50:30:20)	2.81^{f}	3.22^{a}	3.28^{a}	2.89^{b}	2.33^{d}	2.83^{d}
S-G-R (50:40:10)	3.08^{c}	3.17^{a}	2.56^{b}	2.92^{a}	2.97^{c}	2.92^{d}
S-F (50:40:10)	3.89^{a}	3.83^{a}	3.19^{a}	2.47^{c}	3.94^{a}	3.39^{a}
S-C (50:40:10)	3.50^{a}	3.56^{a}	3.50^{a}	3.08^{a}	2.92^{d}	3.44^{a}
S-D-Dr (50:40:10)	3.39^{b}	3.50^{a}	3.53^{a}	2.86^{b}	2.83^{d}	3.17^{c}

Means bearing different superscripts within the same column are significantly different ($p<0.05$).

Key: S = Soaked; G = Germinated; R = Roasted; F = Fermented; D = Dehulled; C = Cooked; Dr = Dried.

The samples were thereafter presented to 49 panelists from different socio-economic groups of mothers and fathers in Turiani (Mvomero district) in Morogoro region for more sensory evaluation and the results were as shown in Table 16.

Table 16: Mean scores of sensory characteristics of porridges of formulated flour at Turiani Hospital

Sample[1]/Proportion	Characteristic mean scores				
	Appearance	Colour	Odour	Consistence	Overall acceptability
S-G-R (60:20:20)	3.98^a	3.94^a	3.88^a	3.84^a	3.82^a
S-F (60:20:20)	3.06^c	3.51^b	2.29^c	3.57^b	2.41^d
S-D-R (60:20:20)	3.78^a	3.86^a	3.84^a	3.78^a	3.74^a
S-C (60:20:20)	3.80^a	3.57^a	3.53^a	3.45^b	3.47^a
S-D-Dr (60:20:20)	3.49^b	3.37^c	3.22^b	3.43^b	2.94^c
S-G-R (50:30:20)	3.90^a	4.00^a	3.96^a	4.12^a	3.86^a
S-F (50:30:20)	3.22^c	3.02^d	2.37^c	3.12^c	2.08^d
S-D-R (50:40:10)	4.06^a	3.65^a	3.45^a	3.59^b	3.47^a
S-D-R (50:30:20)	4.02^a	3.94^a	3.49	3.80^a	3.53^a
S-C (50:30:20)	3.90^a	3.69^a	3.65^a	3.94^b	3.29^b
S-D-Dr (50:30:10)	3.78^a	3.94^a	3.80^a	3.74^b	3.53^a
S-G-R (50:40:10)	3.31^c	3.65^a	2.90^c	3.31^c	2.92^c
S-F (50:40:10)	3.12^c	3.29^c	3.51^d	3.06^d	2.43^d
S-C (50:40:10)	3.92^a	3.86^a	3.71^a	3.52^b	3.59^a
S-D-Dr (50:40:10)	4.08^a	3.86^a	3.88^a	3.82^a	3.96^a

Means bearing different superscripts within the same column are significantly different ($p<0.05$).

Key: S = Soaked; G = Germinated; R = Roasted; F = Fermented; D .= dehulled; C = Cooked; Dr = Dried.

4.3.1 General evaluation results

Panelists detected significant difference ($p<0.05$) among the samples in appearance, odour, taste, consistency and the overall acceptability. However, there was no significant difference in colour among the sample ($p>0.05$), thus was generally acceptable.

4.3.1.1 Percentage score results for the characteristics with least mean scores (<3.0)

Regarding appearance, odour, taste, consistency and overall acceptability, significant differences were detected among the samples with different cassava, soybean and finger millet proportions obtained in different processing techniques (Tables 15 and 16). Both results from Sokoine University and Turiani (Mvomero district) indicated that sensory chacteristics of most of the formulated weaning foods were above 3.0 on a five point hedonic scale, thus acceptable. However, some of the formulated weaning foods were below 3.0 points (Table 15 and 16) as summarized in Table 17.

Table 17: Least mean score sensory characteristics of formulated weaning food

Processing Technique[1]	Percentage mean scores				
	Appearance	Odour	Taste	Consistency	Overall acceptability
S-C (60:40:10)	2.83	-	-	2.92	-
S-D-Dr (60:40:10)	2.81	-	2.86	2.83	2.83
S-G-R (50:30:20)	-	2.72	2.78	-	2.97
S-F (60:20:20)	-	2.29	2.53	2.97	-
S-F (50:30:20)	-	2.37, 2.94	2.17	-	-
S-F (50:40:10)	-	2.51	2.47	-	-
S-G-R (60:40:10)	-	2.56, 290	2.92	2.97	2.92
S-G-R (60:20:20)	-	-	2.86	-	-
S-D-Dr (50:30:20)	-	-	2.89	2.33	-
S-D-Dr (60:20:20)	-	-	2.97	-	-
S-C (50:30:20)	-	-	2.78	-	-
Proportion of 15 Samples (%)	13.30	33.30	53.30	46.70	20.00

Key: S = Soaked; G = Germinated; R = Roasted; F= Fermented; D = Dehulled; Dr = Dried; C = Cooked.

The proportions of the cassava, soybean and finger millet did not contribute much to the influence of appearance in the formulated weaning foods in the study (Table 17). The formulated products were about 87% acceptable in appearance. The lowest preferences in appearance of soaked-cooked (50:30:20) soybean-based formulated weaning food might have been contributed by the overall brownish appearance of soaked-cooked soybean and the brownish colour of the finger millet. Odour of the formulated cassava-soybean products was 66.6% acceptable (Table 17). The panelists did not prefer odour of soaked-fermented formulations. It contributed 50% of the 33.3% of the least scored in odour (Table 17). The increase of soybean proportions in soaked-germinated-roasted soybean formulations probably was associated with undesirable odour that was not preferred by the panelists (Table 17).

Soaking-germinating-roasting and soaking-fermenting techniques did not impart desirable taste to the panelists. Those formulated weaning foods in three different proportions of cassava, soybean and finger millet were among the least mean score by the panelists in taste (Table 17). Further results indicated that the increase of soybean proportions to the soaked-dehulled-dried weaning food formulations would result in the objectionable taste of the products (Table 17). The consistency of the formulated weaning foods in this study was influenced by the increase of soybean proportions in soaked-cooked, soaked-dehulled-dried and soaked-germinated-roasted soybean (Table 17). However, less preference in consistency was also observed in soaked-fermented (60:20:20) and soaked-dehulled-dried (60:20:20) formulated weaning foods (. The overall acceptability was about 80% of the formulations (Table 17). Least preference in overall acceptability was detected in the formulated weaning foods with 30 and 40% soybean proportions in soaked-germinated-roasted formulations and the formulations with 40% soybean in soaked-dehulled-dried. All the evaluated sensory characteristics for soaked-dehulled-roasted soybean formulations were above 3.0 points for all proportions indicating general acceptability of these samples.

High overall acceptance of odour of the formulated weaning foods by 67.7% in the study was probably due to the leaching out of phenolic and other organic compounds associated with beany flavour during overnight soaking of the soybean (Lecomte *et al.*, 1993) and when this was followed with 30 and/or 60 minutes boiling there would be significant influence on beany flavour that could make the product acceptable even at a ratio of 40% soybean. Simple roasting was reported to enhance food ingredients with flavour including aroma and taste. In the study there was significant reduction of beany flavour by roasting the beans at 150°C for 15 min. This could be due to the fact that roasting gives rise to a number of volatile flavour components (Ramamani *et al.*, 1996).

4.4 Antinutritional and toxic constituents

The presence of antinutritional factors was reported as one of the major drawbacks limiting the nutritional and food qualities of legumes (Salunkhe, 1982) and in some cereal grains. Antinutrients are compounds with adverse nutritional and physiological effects. For that reason, a necessity to evaluate these factors in the soybeans and finger millet to be used for weaning food formulation was obvious. Cassava was reported to contain cyanide that can be high in some varieties than lethal dose of 0.5 -3.5 mg HCN per kilogram body weight (Bradbury *et al.*, 1991) or 40-60 mg /kg for an adult (Obiola, (1972) cited by Collins and Temalilwa, (1981). However, malted finger millet is also characterized by the presence of HCN that requires its level to be established prior to formulation.

4.4.1 Tannins and phytates

4.4.1.1 Tannins

Tannins in processed soybean, malted finger millet and raw-dried soybean control were determined and the results were as shown in Table 18.

Table 18: Amount of catechin equivalent (%) in soybean and finger millet*

Sample	Catechin equivalents	%Reduction
Soaked-germinated-roasted soybean	0.17	59.50
Soaked-fermented soybean	0.22	47.60
Soaked-dehulled-roasted soybean	0.19	54.00
Soaked-cooked soybean	0.29	30.00
Soaked-dehulled-dried soybean	0.22	47.60
Raw soybean	0.42	
Malted finger millet	0.35	

Key: *Values are means of triplicate determinations.

The results for tannins in the study were compared to the classified tannins group as adopted by Gomez *et al.* (1997) in Table 9.

Tannin in processed soybean, finger millet and raw-dried soybean control was determined and the results revealed a range 0.17% in soaked-germinated-roasted soybean to 0.42% in raw dried soybean control (Table18). According to Gomez *et al.* (1997), most of processed soybean and germinated finger millet were found to contain low tannin content (Table 18 and 9). However, the amounts of tannins in soaked-cooked (0.29%) and raw-dried (0.42%) soybean were classified as products with high tannin content (Table 18 and 9). A high reduction of tannin to 59.5% was observed in soaked-germinated-roasted soybean while the lowest (30%) was in cooked soybean. In the soaked-fermented tannin was reduced by 47.6% while in soaked-dehulled-roasted and soaked-dehulled-dried 54.0 and 47.6% reductions of tannin, respectively were observed. Most of tannins in the seeds were located in the seed coat with only traces in the cotyledons (Ravindran and Ravindran, 1988; Josephine and Janardhanan, 1992). The soaking of the soybean for 12 h followed by dehulling significantly reduced the amount of seed coat tannins, while most of cotyledon tannins were reduced through 30 and/or 60 min boiling. Soaking the beans in water resulted in elimination of haemagglutinating activity and significant reduction in tannins (Sathe and Salunkhe, 1981, Kadam and Salunkhe, 1985). Dehulling significantly reduces alkaloids, tannins and other polyphenols in pigmented seeds that are not only irritant but also induce allergies in infants (Kadam and Salunkhe, 1985). The lowest tannins reduction obtained in the soaked-cooked soybean was probably contributed by the retention of seed husks during processing. On the other hand low tannins reduction (47.6%) in soaked-fermented soybean was probably due to a release of assayable tannins formerly bound to proteins and other organic substances during mould fermentation (Dashpande *et al.*, 1982).

4.4.1.2 Phytates

Soybean contains phytic acid that may chelate metal ions, such as zinc, iron and calcium in the gut and render them u navailable i n t he b ody. A nalysis o f phytates in the processed soybeans and finger millet before weaning formulation gave the phytate levels shown in Table 19.

Table 19: Phytate content (%) in processed soybean and finger millet

Sample	Phytate content *	% Reduction
Soaked-germinated-roasted soybean	0.59	67.04
Soaked-fermented soybean	0.57	68.16
Soaked-dehulled-roasted soybean	0.58	67.59
Soaked-cooked soybean	0.66	63.13
Soaked-dehulled-dried soybean	0.56	68.71
Finger millet	1.08	
Raw soybean	1.79	

Key: * Values are means of triplicate determinations.

In this study, phytate was determined and ranged between 0.57% in fermented soybean and 1.79% in raw soybean. Reduction of phytate to a range between 63.1 and 68.7% due to soybean processing was obtained (Table 19). Soaked-germinated-roasted soybean contained the original 0.59% phytate was reduced by 67.0% while 0.58%, 0.58%, 0.66 % and 0.56% with respective reduction by 68.2, 67.6, 63.1, and 68.7% phytate were found in soaked-fermented, soaked-dehulled-roasted, soaked-cooked and soaked-dehulled-dried soybean respectively (Table 19). Overnight soaking did not reduce phytic acid but boiling, germination and fermentation reduced it to significant level (Damardjat *et al.*, 1996, Bau *et al.*, 1997 and Preet and Punia, 2000).

During fermentation, there is a reduction of 50% phytic acid (Damardjat *et al.*, 1996). A 17% decrease of phytic acid would be observed in soybean seeds after a five-day germination (Bau *et al.*, 1997). However, rapid degradation would occur from the 9^{th} day of germination and 50% reduction of phytic acid would probably be observed on the 12^{th}day of germination (Chandrasin, (1989) cited by Bau *et al.*, 1997). Reduction of phytic acid to 67.0% probably was contributed by roasting the germinated soybean at 150°C for 15 min. Soaking for 12 h, dehulling of soaked seeds and germination contributed to significant reduction of the phytic acid and polyphenol contents (Preet and Punia, 2000). Cooking the beans in water with or without pressure increases the protein quality and carbohydrate digestibility and it inactivates protease and amylase inhibitors. The process also reduces the concentration of other antinutritional factors (Iyser *et al.*, 1980, El-Tahbey Shehata, 1992), such as tannins and phytic acid. Therefore, there is need for exploitation of such processes in the production of weaning foods that are soybean-based

4.4.2 Hydrogen cyanide

Fermented cassava and malted finger millet used for weaning food formulations were assessed for hydrogen cyanide content before formulation and the results were as presented in Table 20.

Table 20: Hydrogen cyanide content (mg/100g) in cassava and malted finger millet (on dry weight basis)*

Sample	HCN
Fermented cassava	8.3
Malted finger millet	22.1
Unfermented cassava	15.4

Key: *Values are means of triplicate determinations.

The level of HCN in fermented cassava was 53% lower than amount found in cassava control. Malted finger millet contained much higher HCN than the sweet cassava variety selected and used in this study (Table 20). This amount of HCN was expected to be much lower than 10 mg/kg allowance recommended for Africa (Saidu *et al.*, 2003) after blending with other ingredients like soybeans. However, on boiling the formulated products during preparation of porridge or gruel the possibility of having HCN free diet was high. The African popular method of cassava preparation through fermentation of cassava roots by soaking followed by sun drying was reported as one of the effective methods of cyanogens removal (Oke, 1994).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Cassava-soybean based weaning food supplemented with finger millet in the study was a promising solution to protein-energy malnutrition in infants, pregnant and lactating mothers, especially in rural based population that form 80% of the Tanzania population. Cassava is locally available in almost all the regions of Tanzania. Despite its potential in ensuring food security in the household it has been underutilized due to low protein content. Cassava roots are considered as inferior food crop by many eaters with respect to protein content and is blamed to be a source of malnutrition when consumed without protein enrichment. Soybean on the other hand is an excellent source of quality protein but having utilization limitations due to the presence of undesirable beany flavour that affects organoleptic qualities and possession of antinutritional factors. These antinutritional factors affect both cationic divalent minerals and protein bioavailability. Using soybean and cassava, both have added advantage in the food formulation especially in terms of protein and energy status of the food. Cassava and soybean are a good source of energy. The use of both cassava and soybean increases the energy content of the formulations and could thus help to reduce energy malnutrition. On the other hand soybean increases and improves the protein quality of the formulations and could be of great benefit in reducing protein malnutrition.

Soaked-fermented, soaked-germinated-roasted, soaked-dehulled-roasted, soaked-cooked and soaked-dehulled-dried in the ratio of 50:30:20 fermented cassava: soybean: malted finger millet were found to be the most suitable proportions for weaning food formulation.

These had protein content above 15%, which was higher than FAO/WHO (1994) and Tanzania standard values and most of commercial weaning foods (Lactogen-1 & -2). Proportions with 40% soybean, 50% cassava and 10% finger millet were excellent in protein and energy content. The same proportions for soaked-fermented, soaked-dehulled-roasted and soaked-dehulled dried soybean formulations had protein content above 20%, which was higher than FAO/WHO/UNICEF (1971) (PAG) recommended value. However, amount of fat was too high in most of the 50:40:10 proportions to meet keeping quality requirements especially under tropical conditions. This formulation could be very beneficial for piecemeal production of weaning foods that are to be within few days of consumption.

Soybean processing techniques (soaking, germination, fermentation, roasting, cooking and drying) had added advantage on the soybean utilization. These processing techniques had positive effect on undesirable beany flavour characteristic of soybean. About 80% of the formulated products were generally acceptable regardless of the 53 and 33% of the products containing undesirable taste and odour, respectively. Processing techniques reduced antinutritional factors to significant levels. Soaking and fermentation of soybean was a superior technique on product nutrients enrichment with tannins and phytates reduced to 47.6 and 68.2%, respectively. Soaking and roasting of soybeans on the other hand was a superior technique on the improvement of the resulting formulation flavours. Soaking and cooking of soybean also improved the flavour of the resulting formulations and was generally acceptable regardless of the increase on soybean proportions to 30 and 40%. Tannins and phytates were reduced to 30.0 and 63.1%, respectively through soaking and cooking.

Soaking and germination of the soybeans did not improve significantly levels of nutrients and flavours of the resulting formulations. The same product, with exception of soaking and cooking the soybeans, was poor on protein levels. The products had also poor organoleptic qualities. These formulations in higher proportions of soybean (30 and 40%) were generally unacceptable. Soaked, dehulled and dried soybean was limited on the use of low soybean proportion and the product was not accepted organoleptically when soybean proportions increased to 40%.

Energy balance in kilocalories and micronutrients in the formulated weaning foods were below the minimum daily recommended by FAO/WHO (1994) allowances. However, the formulations had energy content above minimum requirements recommended by FAO/WHO/UNICEF (1971). The effect of finger millet supplementation in the formulated products did not change micronutrient content significantly due to the fact that soybean itself is also an excellent source of some minerals such as calcium and iron. Fat content in soaked-fermented, soaked-dehulled-roasted and soaked-dehulled-dried soybean treatments was too high for keeping under tropical condition and the highest fat content was observed in the soaked-dehulled-roasted soybean. Fat content in soaked-cooked and soaked-germinated was not too high to have keeping effect under the same conditions. Even though for short tem use still the high fat levels could be tolerable.

5.2 Recommendations

With cassava being locally available in almost all the regions of Tanzania, soybean needs to be integrated in cassava farming systems to make both crops readily available to farmers for nutritious household food. Emphasis on cassava-soybean farming system integration needs to go parallel with appropriate processing and utilization technologies for both crops to enable availability of suitable balanced nutritious foods for household. In West Africa, soybean is regarded as hard to cook legume. Introduction of such unfamiliar crop in the food habit of rural Tanzania should therefore start with simple processing technologies (soaking-cooking) to complex technologies like fermentation as workable ways of optimizing use of nutrients in the soybean and cassava.

Cassava-soybean combination in the study was superior in protein content but the resulting products were inferior in micronutrients and total energy balance in comparison with FAO/WHO (1994) requirements. Therefore, these products need to be supplemented with micronutrients (minerals). All the formulated products were moderately acceptable probably due to soybean beany flavour or unfamiliarization of such new product in the community. Consequently, more efforts are needed to make the products familiar and acceptable in the community, particularly in the rural-based community, where other sources of protein and energy are difficult to sustain all the year round. The processed soybeans were excellent in protein. Further studies are required to assess the protein quality in terms of essential amino acids and/or protein efficiency ratio (PER) of the processed soybean-based products on the five processing techniques used in the study. The observed low score in acceptability in appearance (13.3%), odour (33.3%), taste (53.3%), consistency (46.7%) and the overall (20.0%) warrant more research for improvement in order to increase acceptability of the products.

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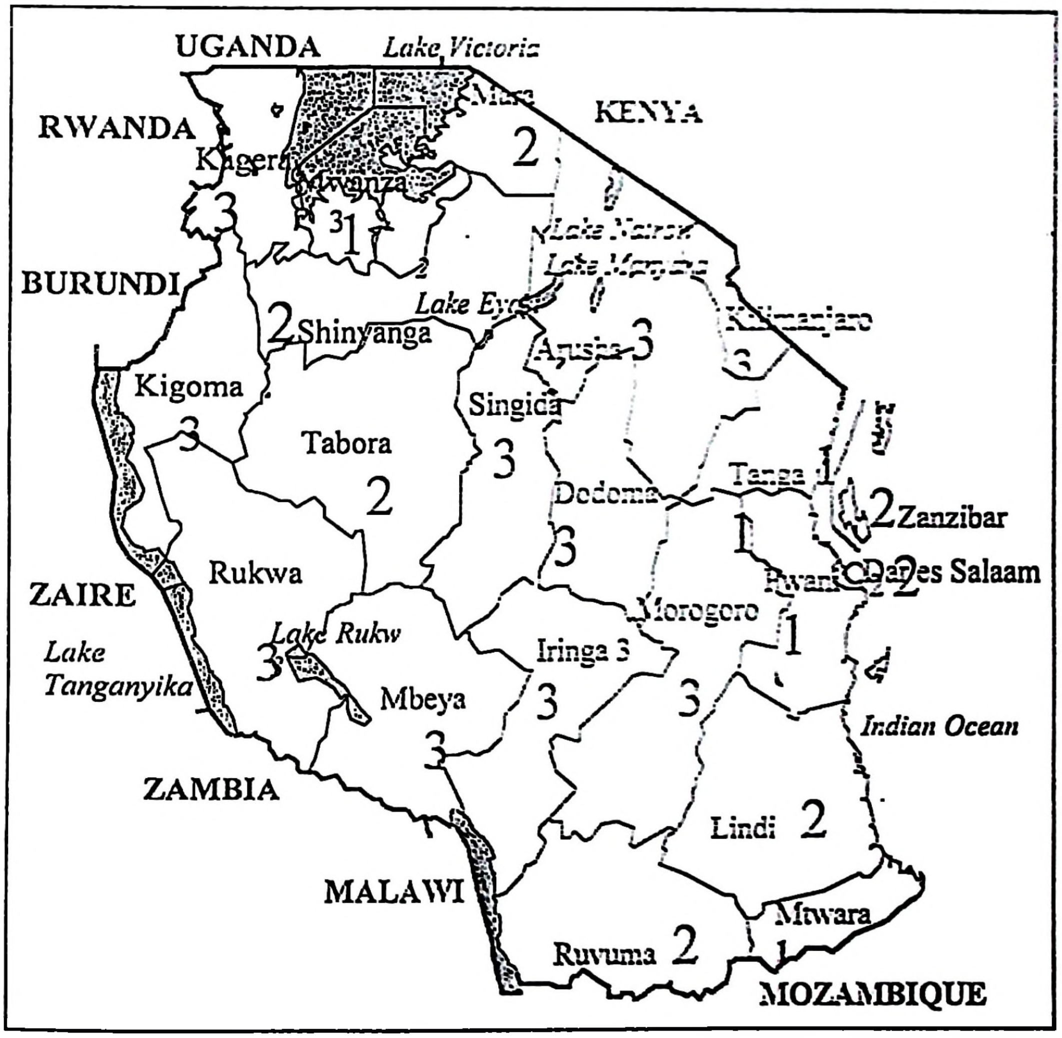
APPENDICES

Appendix 1: Tanzania - cassava production regions



Key: 1-*H*igh cassava concentration area

2-*M*oderate cassava production area 3-Small scale cassava production

Appendix 2a: Total energy distribution from different nutrients in cassava, soybeans and finger millet

Sample	Energy distribution (kcal/100g)		
	Fat	Protein	Carbohydrate
Soaked-germinated-roasted soybeans	192.66	165.04	86.0
Soaked-fermented soybeans	254.64	187.63	61.59
Soaked-dehulled-roasted soybeans	260.58	182.29	49.6
Soaked-dehulled-dried soybeans	225.45	164.08	75.0
Soaked-cooked soybeans	256.02	185.96	49.1
Fermented-cassava	3.24	7.92	379.3
Malted finger millet	5.25	39.60	339.8
Unfermented cassava	7.12	5.10	375.4
Raw soybean	151.17	176.49	148.54

*Values are means of triplicate determination

Appendix 2b: Total energy distribution (kcal/100g) from different nutrients in cassava-soybean weaning food formulations supplemented with finger millet *

Sample	Total energy Distribution		
	Fat	Protein	Carbohydrate
Soaked-germinated-roasted soy formulation			
60:20:20	43.98	46.56	279.32
50:30:20	61.44	62.65	251.94
50:40:10	85.50	73.85	227.83
Soaked-fermented soy formulation			
60:20:20	56.91	49.49	274.78
50:30:20	83.16	68.76	244.90
50:40:10	110.97	84.26	219.80
Soaked-dehulled-roasted soy formulation			
60:20:20	64.74	48.21	271.86
50:30:20	87.33	67.80	240.22
50:40:10	112,20	82.53	213.80
Soaked-dehulled-cooked soy formulation			
60:20:20	51.30	42.99	277.72
50:30:20	75.03	61.32	247.51
50:40:10	92.88	73.41	223.13
Soaked-dehulled-dried soy formulation			
60:20:20	56.64	48.61	273.97
50:30:20	83.19	66.36	244.26
50:40:10	107.07	82.77	215.76

*Values are means of triplicate determination.

Appendix 3a: Panelists sensory characteristic mean scores- Sokoine University

Panelists	Mean scores					
	Appearance	Colour	Odour	Taste	Consistency	Overall acceptability
1	3.73	3.93	3.60	3.93	4.13	3.60
2	2.87	2.93	3.60	2.87	3.20	3.20
3	2.87	3.20	2.87	2.53	2.33	2.87
4	2.80	2.80	2.87	2.27	2.53	2.33
5	3.73	3.73	3.33	2.60	3.33	3.60
6	3.20	3.27	2.47	2.60	2.87	2.53
7	3.73	3.60	3.67	2.47	3.73	3.40
8	3.53	3.47	3.13	2.47	3.27	2.73
9	3.27	3.47	3.07	2.67	2.80	3.13
10	2.93	2.87	3.27	2.00	3.40	2.93
11	3.13	2.87	3.20	2.60	3.00	2.93
12	2.20	2.60	3.00	1.87	2.60	2.40
13	3.00	3.07	3.47	3.07	3.13	3.13
14	3.67	3.67	3.27	3.00	3.87	3.33
15	3.53	3.60	3.07	2.80	3.07	2.80
16	4.07	4.00	3.33	3.67	3.47	3.47
17	3.47	4.13	3.53	2.93	3.20	3.67
18	3.73	4.00	4.00	3.93	4.00	4.13
19	3.07	3..13	3.00	2.53	3.00	3.33
20	2.67	2.93	2.80	2.93	2.20	3.20
21	3.33	3.13	2.40	3.20	2.07	3.20
22	3.40	3.33	3.40	3.07	3.33	3.07
23	3.07	3.07	3.47	2.60	3.20	3.00
24	4.20	4.33	4.60	3.53	4.60	4.40
25	3.27	3.67	3.93	3.33	2.06	3.27
26	3.47	3.53	3.67	3.60	3.13	3.80
27	3.47	3.67	3.47	3.27	3.13	3.27
28	4.20	4.20	2.00	3.07	2.67	4.07
29	2.93	3.33	3.67	3.87	3.33	3.47
30	2.73	2.53	2.27	1.93	2.80	3.47
31	3.47	3.53	3.20	3.13	3.93	3.53
32	2.53	2.60	2.60	2.40	2.47	2.53
33	3.53	3.40	3.40	3.47	3.40	3.67
34	2.53	3.07	2.87	2.67	2.87	2.80
35	3.13	3.13	3.40	3.27	3.07	3.13
36	3.67	3.53	3.80	3.00	3.20	3.33

Appendix 3b: Panelists sensory characteristic mean scores - Turiani

Sample No	Characteristic Mean Scores				
	Appearance	Colour	Odour	Consistency	O/acceptance
1	3.73	3.80	3.80	4.00	3.33
2	4.46	4.13	3.07	3.73	3.00
3	3.67	3.67	3.40	3.93	3.80
4	3.60	3.60	3.13	3.87	3.33
5	3.87	3.87	3.33	3.40	2.93
6	2.60	2.80	2.60	3.53	1.67
7	3.47	3.47	3.47	3.47	4.47
8	3.60	3.67	3.20	3.67	3.13
9	3.40	3.40	3.53	4.53	3.87
10	4.07	3.93	3.60	3.20	2.80
11	3.87	3.73	3.73	3.67	3.27
12	3.67	3.67	3.53	3.27	3.00
13	2.93	2.73	2.87	3.53	3.07
14	3.33	3.40	2.93	3.67	2.87
15	3.87	3.87	3.27	3.73	3.53
16	3.80	3.67	3.00	3.80	3.20
17	4.27	4.33	3.07	3.80	3.47
18	3.87	3.73	3.13	3.80	3.13
19	4.13	4.00	4.27	4.47	3.67
20	3.80	3.40	3.20	3.20	3.13
21	4.07	3.80	3.60	3.60	3.53
22	3.40	3.60	3.33	3.27	2.87
23	4.40	4.47	4.00	3.87	3.80
24	4.67	4.86	3.80	4.40	3.40
25	4.53	4.53	3.07	4.27	3.40
26	2.00	3.00	3.47	4.13	3.20
27	3.87	3.93	4.07	3.47	3.93
28	2.93	3.07	2.87	3.60	2.60
29	4.27	4.73	4.13	4.20	2.60
30	3.67	3.40	3.20	3.13	3.47
31	3.27	3.60	3.33	3.20	3.47
32	3.73	3.67	3.20	3.53	3.40
33	3.33	3.67	3.00	3.13	3.27
34	3.40	3.73	3.00	3.20	3.00
35	4.13	3.93	3.40	3.67	3.67
36	3.93	4.07	3.27	3.07	2.80
37	4.27	4.13	4.13	4.00	4.00
38	3.67	4.20	3.53	4.13	4.07
39	3.46	3.13	3.33	3.93	2.60
40	4.27	3.87	3.20	3.40	3.67
41	3.80	3.40	3.47	3.80	3.87
42	3.53	3.93	3.87	4.13	3.27
43	2.93	3.00	2.80	3.07	3.27
44	3.53	3.20	3.00	3.40	2.87
45	4.00	3.27	3.53	2.40	2.53
46	3.80	3.40	3.07	2.67	2.40
47	2.47	4.00	4.20	4.13	4.00
48	3.33	2.27	2.87	2.27	2.40
49	4.33	3.07	3.00	3.00	2.13