UTILIZATION OF SORGHUM, MILLET AND AMARANTH FOR THE DEVELOPMENT OF HIGH ENERGY WEANING FOODS FOR KENYAN PRE-SCHOOL CHILDREN

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DEPARTMENT OF FOOD TECHNOLOGY AND NUTRITION
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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

D.O. BUSOLO

This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

This work is dedicated to my husband William W.S. Busolo and children, Seth, Peter, Melanda and Aggrey Busolo.

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Abstract

The weaning period defined as the period in a young child's life when supplementary foods are introduced to complement breast milk poses great nutritional risks to children in Kenya. Traditionally unfermented cereal porridge made from maize, sorghum or millet flour is usually fed to Kenyan children during the weaning period of four months to five years. These cereal flours are low in protein especially lysine as a limiting amino acid in most cereal grains. The flours are also high in bulk and subsequently there is a high water and low nutrient intake during consumption of porridges made from the flours. Several antinutrient factors complex certain amino acids in the sorghum *(Sorghum vulgare)* and fingermillet *(Eleusine coracana)*. This study was aimed at developing weaning flours from sorghum, millet and amaranth grains.

The work undertaken encompassed the preprocessing technologies of dehulling, malting and grinding and mixing of flours to make weaning flours. Sorghum and millet flour were blended with *Amaranthus hypochondriacus* to make high protein flours. The flours were made into a stiff porridge (ugali) and fed to rats whose weekly growth weight and feed intake were monitored.

The following observation were made: malting of sorghum significantly ($p<0.01$) reduced flour water holding capacity (WHC) from 112.90% to 89.06%. Dehulling significantly ($p < 0.05$) reduced the WHC to 98.38%. The WHC of amaranth flour was 112.75%. On malting sorghum the energy content in a slurry with a viscosity of 1600 cp

was significantly ($p<0.01$) increased from 114.38KJ (ungerminated) to 126.06KJ (germinated). To get a standard porridge slurry of 1600 cp, 5.5% of amaranth flour, 5.0% of unmalted sorghum flour was used. But when malted 7.0% sorghum flour was used. This implied that 2% more malted flour could be added to the porridge giving the same viscosity as 5% unmalted flour.

24 hours of malting was adequate. Malting of sorghum for 48 hours had no significant ($p<0.05$) effect on viscosity. The In Vitro Protein Digestibilities (IVPD) was 55.00 for unmalted sorghum, 57.60 for dehulled sorghum and 60.30% for malted sorghum. The In Vitro starch digestibility (IVSD) was 44.25% for unmalted sorghum, 68.36% for dehulled sorghum and 72.5% for malted sorghum. The In Vitro Starch Digestibilities (IVSD) was 44.25, 68.36, and 72.5% for the ungerminated, dehulled and malted sorghum respectively.

The In Vivo Starch Digestibility (IVVSD) increased significantly ($p<0.05$) from 60.80 to 66.65% on dehulling and to 76.65% on malting. The In Vivo protein Digestibility (IVVPD) also increased significantly from 55.65% to 65.5% on dehulling and to 67.75% on malting. Both dehulling and malting increased digestibility.

The Protein Efficiency Ratio PER of the unmalted sorghum-amaranth diet was increased from 0.4 to 1.43 on malting and to 0.94 on dehulling.

The WHC of fingermillet significantly ($p<0.05$) decreased from 79.96% to 70.34% on malting whereas the energy content increased significantly ($p<0.05$) from 127.75KJ to 221.24 KJ when 9.5% of unmalted fingermillet flour and 16.2% of malted fingermillet flour respectively were added to give the slurry viscosity of 1600 cp. The In Vitro Protein Digestibility increased significantly ($p<0.005$) from 58.80% to 78.50% on malting of the grain. The In Vitro Protein Digestibility increased from 64.68% to 78.58 % on malting. The In Vivo Starch Digestibility increased from 70.92% and 83.898% after malting of the fingermillet. The PER of the unmalted fingermillet was 1.61 whereas that of malted was 2.05. Addition of premix increased the PER from 1.61 to 3.66 and 2.88 for the unmalted and germinated millet amaranth cooked flours respectively.

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1.0 INTRODUCTION

Sorghum and millets were widely cultivated in Kenya prior to the turn of the century and formed the basic diet of a large percentage of the population in the country and other parts of East Africa (Majizu, 1988). They form an important group of cereals for human consumption in the Savannah zone of Africa, in addition to the insignificant role they play in the cash economy. Nearly 70% of dietary protein and energy intake in Africa are supplied locally by sorghum and millet products. Millions of children are weaned with food products made from these grains (Seenappa, 1987).

The government of Kenya attaches great importance to these cash crops, since they thrive in the arid and semi arid areas of the country better than maize. The establishment of a national programme of Research and Improvement of Sorghum and Millet (PRISM) in 1982 supported by public funding reaffirmed government commitment to the policy to supporting sorghum and millets production (Majisu, 1989). Notably, the main objective of PRISM is to sustain the level of research and experimental development activities especially in the area of processing and product development in order to enhance the place of sorghum and millet in the overall national cereals policy.

The study aims to further the objectives of PRISM by developing weaning foods based on sorghum and millet.

According to UNICEF report (1987) more than 30% children in the world suffer from moderate malnutrition each year, with 5% being severely malnourished mainly due to protein-energy malnutrition (PEM). Malnutrition is manifested during the weaning period, at the age of 4 months to 5 years.

A report on infant feeding in Kenya by Oniang'o and Alnwick (1987) showed that unfermented cereal porridge is usually the initial weaning food given to majority of children. The cereals used included sorghum *(Sorghum vulgare),* fingermillet *(Eleusine coracana)* and bulrush millet *(Pennisetum typhoideum)* with fingermillet being the most preferred. The report concurs with the current observations made in the urban supermarkets where composite flours of cassava, maize meal, millet and sorghum are commonly sold and used to serve as weaning diets for the preschool children (Personal Communication). Porridge flours prepared from such flours are fed to children in addition to the commercially available preparation such as cerelac (Personal Communication). Oniang'o and Alnwick (1987) also reported that fermented porridges which are low in bulk and high in acid are exclusively taken by children over 12 months of age. Acid hydrolysis reduces bulk. Accordingly the majority of children beyond 4 months and less than 12 months are fed on non fermented porridges which have a higher water than solid content.

Weaning foods currently available commercially and prepared from cereals and legumes are made by roller drying or extrusion cooking of paste to reduce the dietary bulk by dextrinization of starch through high temperature cooking (Fapojuwo et al., 1987). These

products tend to be too costly to be affordable by the majority of the population in developing countries (Desikachar, 1980a). It is therefore necessary to explore an alternative technology for producing weaning foods, using local materials which are affordable. The technology must ensure high nutrient and energy density. Two such technologies that are studied in this research are malting and dehulling.

Traditionally, malting is used in Kenya for brewing traditional beer. It has been reported to be advantageous in increasing the availability of micronutrients, while decreasing the dietary bulk and antinutrient factors (Mosha et al, 1980). When unmalted cereals are used as a starch base in semi-liquid gruel preparations, the energy level is about 0.3 –0.5 Kcal/g. The minimum desirable energy requirement for children 1 – 3 years is 0.7 Kcal/g food intake (Hellstron et al., 1981) When malted sorghum (white) and millet were used to prepare semi-liquid gruel it was possible to reach energy density of 1.0 Kcal/g (Svanberg, 1987).

Sorghum and millets lack two essential amino acids namely, lysine and methionine (Awadalla and Slump, 1974) which limits their using in weaning preparations as exxlusive food source. *Amaranthus hypochondricus* grain on the other contains 16% of good quality protein with about 5.3% lysine content (Teutonico and Knorr, 1985). Leucine and threonine are the 2 limiting amino acids in amaranth (Malleshi, 1986b). *Amaranthus hypochondriacus* has been recommended as a potential major food source for developing world economies (Proceedings of Amaranthus Conference, 1980).

Considering these qualities, amaranth could be used to improve the protein quality in sorghum and millet-based blended weaning foods.

This study was therefore designed to investigate the possibilities of using sorghum and millet composited with amaranth as a protein source to produce weaning flours pre-school children.

1.1 Hypothesis

Malting of cereals together with or without dehulling leads to products with less bulk and higher energy density and digestibility. The nutritive value of such products can be enhanced by compositing with complementary protein sources such as amaranth.

1.2 Objectives

1.2.1 To evaluate the nutritive value and anti-nutrient factors in sorghum, fingermillet and amaranth (Analysis to involve: Proximate composition and tannins).

1.2.2 To determine the effect of processing (dehulling and malting) on the physical properties and nutritive value of sorghum and millet products entailing In vitro protein digestibility (IVPD), In vitro starch digestibility (IVSD), Water Holding Capacity (WHC), Particle Size Distribution (PSD) and Calorific Value determination)

1.2.3 To develop a weaning diet based on sorghum, millet and amaranth. (To involve the following determinations: viscosity, energy density, protein efficiency ration (PER).

2.0 LITERATURE REVIEW

2.1 Nutrient Value of Grain

2.1.1 Proximate Composition of Sorghum, Fingermillet and Amaranth

The proximate composition and some important nutrient of sorghum (*Sorghum vulgare*) fingermillet *(Eleusine coracana) and Amaranthus hypochandriacus* are given in Tables 2.1, 2.2 and 2.3 and briefly discussed below.

2.1.2 Carbohydrates

Carbohydrates are quantitatively the most important constituents of sorghum, fingermillet and amaranthus. They form about 70-80% of the total dry matter in wheat, barley, maize, sorghum, Millets and rice (Kent et al, 1975). The carbohydrates in cereals include Starch which preponderates cellulose, hemicullose, pentosans, dextrins and Sugars. Carbohydrates are divided into crude fibre that is insoluble in Acids and alkalis under prescribed conditions, and the soluble carbohydrates which is the remainder, after accounting for crude fibre, nitrogenous compounds, fat and mineral matter. Neither crude fibre nor soluble carbohydrate is a pure chemical substance but a knowledge of each is important in relation to nutritional and digestibility of weaning food for children.

Table 2.1: Proximate Composition of Sorghum

Attribute	% Content
A Protein (N x 5.7)	7.1 – 14.2
Lipids	2.4 - 6.5
Carbohydrates	70-80
Fibre	1.2-3.5
a. Amino Acids (mg/gN)	
Lysine	71-212
Lysine amino acid score	21-62
Isoleucine/Leucine	1.9-5.0
a. Minerals (mg/100g)	
Calcium	11 – 588
Phosphorus	167-751
Iron	0.9 – 20.0
a. Vitamin (mg/100g)	
Thiamine	0.24 – 0.54
Niacin	3.9 – 6.4
Riboflavin	0.1 – 0.2
b. Tannin content (Cat Eq.)	0.1 – 5.9%
c. Starch	58 - 70%
d. Amylose	0.79 – 30.66%
d. Reducing sugars (as maltose)	0.21 – 0.4%
d. Non-reducing sugars (as sucrose)	039 – 1.34

Source: a – Hulse et al., (1980

b. – Arora and Luthra (1974)

c. – Miller and Burns (1970)

d. – Jambunathan and Subramanian (1988)

Table 2.2 Percent Proximate Composition of Fingermillet

Attribute	Content
Protein (N x 5.7)	3.8 – 10.9%
Lipid	1.0 – 4.8%
Carbohydrate	74-88%
c. Fibre	3.0 – 7.5
d. Reducing sugar	0.21 – 0.41%
Amino Acids (mg/gN)	0.8 – 1.8%
Lysine	160 – 262
Lysine Amino Acid score	47 – 77
Isoleucine/leucine	1.5 – 2.9
b. Tannins	0.03 – 3.4%
Minerals (mg/100g)	
a. Calcium	220 – 855
Phosphorous	131 – 1102
Iron	26 – 50
Vitamin (mg/100g)	
Thiamine	0.19 – 0.02
Niacin	0.13 – 2.5
Riboflavin	0.06 – 0.16

Source: a – Hulse et al., (1980)

b. – Table 1.4 Virupaksha et al., 1977

c. – Pore et al., 1979

d. – Mbugua et al., 1983

dm – Dry matter basis

Table 2.3: Composition of Amaranth hypochondriacus

Attribute	Content
Protein	15 – 18%
Fat	3.1 – 6.3%
Cabohydrates	60.7%
Fibre and Vitamins	0.5%
Minerals mg/100g	
Calcium	490
Iron	15
Copper	0.7
Phosphorous	397 – 691
Thiamine	0.26
Riboflavin	0.15
Niacin	1.15
Ascorbic Acid	61.5
Biological value	73.7
Digestibility	80.4
Energy	391Kcal/g
b. Lysine	3.5 – 5.0 %
b. Lysine score	72.8 – 100
c. Starch	48 – 62%
c. Tannin (Cat. Eq. %)	0.054 – 0.065
Amylose	7.2%

Source: a – Perez et al., 1979 in Proceedings of Second Amaranth Conference

b.- Teutonico and Knorr (1985)

c.- Saunders and Becker (1983)

Whereas carbohydrates are responsible for the provision of the basic energy for the body, the fibre holds water so that stools are soft, bulky and it allows for easy bowel movement. Fibre also increases the motility of the small intestines and colon thus decreasing the transit time of food. Both carbohydrates are therefore nutritionally essential for the functioning of the body.

2.1.2.1 Carbohydrates in Sorghum

All cereals constitute a good basis for a young child's diet meeting the basic energy needs. The amount of carbohydrates are able to adequately meet the Recommended Daily Energy needs of 700 Cal/day if fed at least twice a day in the form of porridge or paste (Sbanberg et al., 1987).

Starch is the major component of sorghum and accounts for 55.6 – 75.2% of the grain (Jambunathan and Subramanian, 1988). In sorghum the amylose content varies from 0.79 – 30.66 (Table 2.1). The gelatinization temperature is affected by the proportion of amylopectin to amylose (Hoseney et al., 1984) which in sorghum varies form 66.0 – 70.5% (Subramanian et al., 1980).

The availability of starch in sorghum has been observed to be low due to the presence of polyphenols (Bhise, et. al 1988). The unavailability of sorghum starch is undesirable if it is used as a source of food for weaning purposes. The thickness of the grain pericarp contributes to the undigestibility as it tends to lead to low flour yield and high polyphenol

content. (Youssef et al., 1988). The low tannin sorghum varieties tend to have high starch and flour yields. It is evident that high tannin sorghum flour that is intended for weaning food would need to be dehulled or pretreated in order to reduce the tannin content.

The amount of free sugar in sorghum has been reported to be 0.11% raffinose, 0.09 glucose, 0.09% fructose and 0.85% maltose (Bhise, et. al., 1988). The presence of the total reducing sugar is very low and therefore insignificant in contributing to the overall taste of the gruels made for weaning. The raffinose present is also low and does not usually cause flatulence in diets. Given the cultural preference of sorghum and its food value it can be a suitable source of carbohydrate for food prepared for weaning children.

2.1.2.2 Carbohydrates in Fingermillet

Fingermillet is a very important staple for many people especially in East and Central Africa. However, its use in infant and child feeding is limited due to its poor digestibility attributed to polyphenols and phytic acid (Rajalxmi, 1969). The carbohydrate content of fingermillet is high and ranges from about 68 – 88 %. The reducing sugars range from 1.2 – 2.0 % and starch from 60 – 70.2% (Taur et al., 1984). Starch is therefore the most abundant component of the grain and is able to adequately meet the Recommended Daily Energy requirements for a child who is under five years.

The physico-chemical properties of starches isolated from native and malted fingermillet, pearl millet and foxtail were studied by Malleshi et al., (1986). The starch from malted

fingermillet had lower swelling power, higher solubility in water and low intrinsic viscosity, implying that more flour per unit volume can be incorporated into water before thick past consistencies are achieved in weaning porridge. Fingermillet starch was however found more resistant to amylosysis than pearl millet (Malleshi et al., 1986), although it contained higher levels of amylases than the pearl millet (Shukla et al., 1985). This low amylosis may be disadvantageous in reducing dietary bulk in gruels made for weaning purposes. But when compared to other grains like sorghum and maize during malting, the amylases in fingermillet develops to a great extent making fingermillet a good source of these enzymes (Shukla et al., 1985).

2.1.2.3 Carbohydrates in Amaranth

The carbohydrate content of *Amaranthus hypochondricus* is 53.8 – 63% (Teutonico and Knorr, 1985). The carbohydrate together with the lipids in amaranth which ranges from 3 – 6% (Table 2.3) should be able to supply higher quantities of energy for the child than sorghum and millets discussed above. Starch which is 48 – 64% (Table 2.3) is the main carbohydrate component of the grain (Becker, et al., 1979). Research on the physico-chemical characteristics of the amaranth starch showed that *Amaranthus hypochondriacus* contained about 7.2% amylose with a water binding capacity of 127.3% (Stone and Lorenz, 1984). The water holding capacity is desirable in weaning food because on cooling of the gruels made from the flours, there is no separation of water from the solids thus facilitating ease in feeding. Compared to wheat starch, *Amaranthus hypochondriacus* starch has a higher solubility. It also has lower amylose content and

higher swelling power, (Lorenz and Collins, 1981). The starch in amaranth has a lower amylograph viscosity value on cooling its slurry to 35°C. It has a higher gelatinization temperature. Amaranth could be a suitable composite with fingermillet on account of its low viscosity on cooling. This characteristic could facilitate incorporation of more solids in the weaning porridge, without creating high viscosity pastes.

2.1.3 Proteins

Proteins are involved in the building of new tissues particularly during the rapid growth period in infancy and early childhood. This process requires good protein quality with optimum composition of essential amino acids and energy.

2.1.3.1. Sorghum Proteins

Protein content in sorghum ranges from 4.4 – 21.1% with a mean of 11.4% (Table 2.1) depending on the variety and the conditions under which the crop is grown. Sorghum proteins have been shown to have high levels of glutamic acid, leucine, alanine, proline and aspartic acid compared with other amino acids (Subramanian and Jambunathan, 1988). Lysine has been observed to be the limiting amino acid (Sneenapa, 1987). Eggum et al. (1987) observed that a diet consisting of only sorghum had a low lysine content, and did not allow adequate utilization of protein and energy. If however sorghum was combined with other high lysine grains, the protein and energy were

utilized more effectively. Sorghum protein has also a high leucine to isoleucine ratio. This ratio has been implicated in causing pellagra disease (Skrikantia, 1978).

Deficient levels of lysine, threonine and tryptophan, entailing low protein digestibility would imply poor nutritional value of sorghum based products (Mertz et al., 1981). Sorghum based weaning foods would therefore require supplementation with lysine rich food materials.

2.1.3.3 Amaranth Protein

Amaranthus hypochondriacus has about 16% protein content with high lysine content of 5.0% (Table 2.3). Maize contains 1.0% lysine , rice 3.8% and wheat 3.6% (Senft, 1980). The sulphur amino acids in amaranth protein constitute 4.4% (Senft, 1979). Of additional significance is the fact that in *Amaranthus hypochondriacus*, the essential amino acids, threonine (3.0%). Isoleucine (3.1%), valine (3.7%) and leucine (4.9%), which are found at levels less than recommended FAO/WHO standards (4.0%, 5.0%, 7.0%) in other cereals, are all found in adequate amounts in common *Amaranthus hypochondriaucus*. Thus amaranth grain combined with these grains can provide a protein which very closely approximates the FAO/WHO Protein standard in quality.

2.1.4 Digestibility

2.1.4.1 Digestibility in Sorghum

Whole grain flour of high tannin sorghum when cooked and fed to children, exhibited poor digestibility (Maclean et al., 1981a; 1981b). However, the digestibility was improved considerably when sorghum was fed after processing into *nasha*, a thin fermented baby food in Sudan (Graham and Maclean, 1980 and Graham et al., 1986). Mertz et al., (1981) observed that uncooked sorghum proteins had a high digestibility (78 – 100%) which dropped to 45 – 55% after cooking. This was attributed to the sorghum protein being bound by tannins in slurry on cooking. Pepsin digestibility in other cereals showed that cooking ground whole wheat gruel and ground whole maize gruel did not decrease their uncooked pepsin digestibility values (Mertz et al., 1981).

Fermented products, based on sorghum, namely *kisra* and *abrey* that are sheet-baked gave higher digestibility values of 65 – 86% in a study on digestibility using pepsin (Mertz et al., 1981). In contrast unfermented cooked gruels made in the same laboratory from the same kisra and abrey flour gave pepsin values of only 44 – 56%. It was therefore concluded that fermentation increased the pepsin digestibility of sorghum. Thus fermented sorghum products could be suitable for use as weaning foods.

2.1.4.2 Digestibility of Fingermillets

Though fingermillet flour has a poor digestibility on cooking, it is culturally accepted as a weaning food in Kenya in the form of porridge. Hemalini et al. (1980) assessed the nutritional quality of the sprouted versus the unsprouted fingermillet. Results revealed that, the growth rate in rats fed with sprouted fingermillet was higher that for those fed whole unmalted fingermillet. There was no significant difference between the protein efficiency ratio (PER) between rats fed on unsprouted and sprouted ragi (fingermillet). The retention of calcium was the same for the sprouted and unsprouted ragi. The higher growth rate sprouted ragi was postulated to be due to the higher amounts of B Complex Vitamins and other nutrients availed on malting.

Ifon (1980) carried out a nutritional evaluation of a traditional Nigerian weaning porridge based on fingermillet before and after fortification with soya proteins. The Protein Efficiency Ration, the Net Protein Utilization (NPU) and the biological value of the unfortified millet were 1.22, 49.2 and 53.7 respectively and were significantly $P<0.05$) lower than those of the soya fortified diet viz:- 2.18, 67.56 and 78.93 respectively. It is clear that fingermillet protein require supplementation to improve its amino acid content using protein sources rich lysine.

Metabolic studies with rats using fingermillet flours with 5% protein and a standard egg protein level at the same level gave an average digestibility of 77.5% and biological value

of 90.5% (Hulse et al., 1980). The nutritive value of white fingermillet grain was observed to be superior to the brown type implying existence of antinutrient factors in the brown variety.

2.1.4.3 Digestibility in *Amaranthus hypochondriacus*

Saunders and Becker (1983) reported PER values ranging from 1.5 – 2.0 (compared to casein) for cooked amaranth and digestibility value of 90%. A biological value of 70% for amaranth protein was also reported, compared to 44, 60, 68 and 72 for corn, wheat, soya bean and milk respectively (Saunders and Becker, 1983). The high PER and the digestibility values for amaranth indicate that it might be a suitable source of protein in weaning foods.

2.1.5 Antinutrient Factors

2.1.5.1 Polyphenols

Polyphenols are phenolic hydroxylic compounds which form cross-links with protein and other molecules (Butler, 1988). They occur naturally in plant foods and have molecular weights ranging from 500 – 3000.

2.1.5.1.1 Polyphenols in Sorghum

The major groups of polyphenols found in sorghum are flavonoids, tannins and lignin (Butler et al. 1988). The tannins content in sorghum is 0.1 – 5.9% catechin equivalent

(Table 2.1). Two major nutritional problems have been identified with condensed tannins found in sorghum. They have often been associated with diminished weight gains and feed efficiencies of experimental diets in young animals and humans (Butler et al, 1986). The antinutritional effects associated with high tannin sorghum are considered to be due to inhibition of protein digestion by the dietary tannin and reduced voluntary feed intake (Mcleod, 1982). Evidence is accumulating that the antinutritional effects may largely be due to the protein precipitation by polyphenols with molecular weight of about 576 to those with molecular weight beyond 1134. Further they react with the animal's digestive enzymes and decrease their activity (Hoseney et al., 1988).

Dehulling of high tannin sorghums has been shown to decrease the tannin content and to increase digestibility of the dietary protein in the study animals (Chibber et al., 1980) Thus dehulling is an important processing step for improving the nutritive value of sorghum based products.

2.1.5.1.2 Polyphenols in Fingermillet

Polyphenol levels of 0.02 – 3.47% of tannins have been reported in fingermillets (Virupaksha et al., 1977) and attributed to be the likely cause of the depressed digestibility.

Monteiro et al. (1988) observed that the antinutritional factors (phenols, tannins) are present in fingermillet in very low amounts. Andy et al. (1981) compared the nutrient composition of millets (*Pennisetum typhodeum)* grain and fingermillet malt and reported the presence of very low amounts of oxalate and tannins which decreased on malting of the grain. The utilization of fingermillet in the weaning diets could be improved by grain malting.

2.1.5.2 Phytic Acid

Phytic acid salts (inositol hexaphosphoric ester) have long been known to be constituents of cereals such as sorghum, millets, oil seeds and legumes. They are known to reduce the bioavailability of essential minerals such as calcium, zinc, magnesium, iron, etc. when present in great than 1% of diet (Singh et al., 1982a). This is undesirable in weaning diets. Several workers have also reported that the presence of phytic acid hampers the peptic digestion of the protein in the alimentary canal, and amylase activity in vitro (Murty and Rao, 1984a). A number of proteins of animal and vegetable origin are known to form insoluble stable complexes with phytic acid below their isoelectric point.

2.1.5.2.1 Phytic Acid in Sorghum

Achuta et al. (1965) analysed the phytic acid, the phosphorous content and the phytase activity in various sorghum grains. They reported that from the total of 179mg/100g

phosphorus present in the sorghum, about 38 mg/100 was in combination with phytin. This is about 76% of the total phosphorus. Levels of 77 – 88 % phytin phosphorus were however observed in certain varieties (Grontzca et al., 1968).

Diminished intestinal absorption and retention of calcium due to the presence of phytate have been demonstrated (Murtz, 1984b). Phytate also binds iron, calcium and zinc which is necessary for the conversion of trypsinogen to trypsin (Murty, 1984b), a reaction that can be inhibited by phytate. Phytic acid therefore is undesirable in weaning foods.

Bartnick et al (1987) observed that the phytase activity of cereals increased on malting though the corresponding phytate hydrolysis did not increase significantly. However, they observed a decrease in the phytate content on malting. Similar observation were made by Shukla et al. (1985). Several other workers observed a decrease in the phytate content as a result of sprouting in sorghum and millets and postulated that this could lead to increased availability of certain nutrients (Reddy et al., 1988). They observed a negative correlation between the total phosphorous and phytate phosphorous during germination of cereals and black gram seeds respectively. This was assumed to be caused by the breakdown of the phytic acid by phytase.

2.1.2.2 Phytic Acid in Fingermillet

In fingermillet grain, out of a total of 245mg/100g phosphates present, 172mg/100g was observed to be phytin phosphorous (Hulse et al., 1980). Cooked fingermillet however has 61% phytin phosphorous indicating that cooking of the millet released some of the bound phosphorous (Hulse et al., 1980). It is possible that the phytic acid molecule is split on cooking fingermillet. This could be advantageous in weaning diets preparations.

2.1.5.3 Oligosaccharides in Grain

Oligosaccharides are low molecular weight polysaccharides that are found in cereals and legumes and are responsible for flatulence and gastrointestinal discomfort experienced after consumption of the grains. The oligosaccharides include raffinose, stachynose and verbascose. The levels of raffinose in millet and sorghum are 0.05% and 0.06% respectively (Mbugua et al., 1983). This is lower than raffinose found in cowpeas 1.49 – 5.89% as reported by Onigbinde and Akinyele (1983). Due to the low levels of reducing sugars in sorghum, 0.21 – 0.41% (Table 2.2) the discomfort resulting from their consumption is minimal and therefore they could safely be used in weaning food formulations.

2.1.5.4 Antinutrient Factors in Amaranth

The fatty acids in amaranth comprise about 70% oleic and linoleic acids which are essential for the body. These free fatty acids being unsaturated render poor keeping quality characteristics to weaning foods into which amaranth is incorporated. Tannin and phytic acid levels are low, 0.043 and 0.58% respectively (Teutonico, 1985).

Raw amaranthus seeds have been observed to contain some factor which result in low palatability given to rats. Saponins, oxalates and phenolic compounds which are astringent, are said to be responsible for the low palatability in amaranthus grain (Bronson and Cheeke, 1979). Cooking of the amaranth samples markedly increased the feed intake and growth perfomance of rats indicating that the factor(s) that affect palatability are heat labile.

Mugambi (1986) reported detection by panelists of a slight bitter after-taste sensation in the mouth at 10 to 15% level of amaranth flour substitution in wheat bread. The bitter sensation disappeared a few seconds after testing. Further research is however needed in order to explore better these factors and establish their role in nutrition.

2.2 Malting of Sorghum, Millets and Other Grains

2.2.1 Nutritional Changes on Malting

Malting has been known to enhance the nutritive value of cereals and legumes (Mier et al)., 1986; Marero et al;, 1988). Wang et al. (1978) observed an increase in the Relative Nutritive Value (RNV), lysine, methionine and the tryptophan contents of corn on germination. Malting of grain sorghum has been reported to increase the water soluble protein, lysine, methionine; soluble sugars and the diastatic activity in the malt (Bhise et al., 1988). The process has potential for enhancing the availability of the micronutrients and especially lysine in weaning diets.

Several vitamins have been shown to increase during germination by several researchers. (Waginger et al., 1985). The same researchers observed that apart from the increase in vitamin content, the crude fibre and the protein score were also increased on malting.

Andy et al. (1981) investigated the composition of millets *(Pennisetum typhoideum)* grain and fingermillet malt. They observed that the level of lipids in malt was relatively lower than in grains, while the protein content increased on germination of the grain. It was further observed that fibre increased on malting. Niacin, the major vitamin in the grain was observed to decrease on malting whereas other vitamins increased on malting.

Daudo (1986) studied the weaning foods formulations based on malted sorghum and cowpeas and observed that malting improved PER (2.4) over and above that of non malted material.

From the foregoing, it is evident that the apparent food quality, as determined by proximate chemical analysis can be seriously impaired by many intrinsic and extrinsic adverse substances, which have as yet to be fully understood., Appropriate processing of grain is imperative in order to eliminate the adverse factors, including polyphenols, oxalates, saponnins, phytic acid inorder to preserve the essential nutrients such as protein, vitamins and minerals.

2.2.2 Physico-Chemical Changes on Malting

Leevathi et al. (1987) observed that malting of cereals increased the diastatic activity level of damaged starch, but lowered its water absorption properties which facilitates more flour incorporation in water during gruel preparation.

Some pearl millet varieties have been generally observed to have higher levels of protein, carbohydrate, vitamin and minerals than sorghum (Hoseney, 1984). However, pearl millet has been observed to have a problem of rapidly producing an unacceptable odour, after the grain is milled. This objectionable odour can limit its consumption. On malting

and reduction of the grain moisture to 10% the problem of off-flavour has been reported to be avoided (Hoseney, 1984).

2.2.3 Disadvantages of Malting Grain

Germination of cereals has been shown to induce production of toxic chemicals like hydrocyanic acid in sorghum which in undesirable (Dada et al., 1987). This has however been shown to be eliminated on drying of the grain to a moisture content of 10%. Malting also leads to a decrease in starch content and an increase in sugars due to starch hydrolysis by endogenous amylases (Pathirana et al., 1983). Excessive hydrolysis of the starch during malting is however undesirable for the preparation of traditional products, since it leads to significant losses of dry matter (Bhise et al., 1988).

2.3 Dietary Bulk in Weaning Foods

In many developing countries children are weaned on diets based on the same staple foods the adults use. These foods are mainly cereals like maize, sorghum, millets and tubers like cassava, arrow-roots and sweet potatoes. Small children are normally given gruels made from these staples. When prepared from whole flour, the starch structure bind large amounts of water which results in gruels of high viscosity. Such gruels need to be further diluted with water to give a consistency that is appropriate for child feeding especially when they cool. This dilution however decreases the energy and nutrient density of the gruel, and children take large amount of gruel to satisfy their caloric requirement. Such large quantities of consumption by infants are however impossible. The high volume of low solids ratio which is characteristic of such diets is usually refered to as 'dietary bulk' (Mosha et al. 1987).

Dietary bulk in weaning foods is associated with malnutrition in weaning children due to low energy density in these foods (Protein Advisory Group, 1973; Payne, 1976). Industrial manufacture of cereal-based weaning foods often includes treatment intended to increase energy density such as using amylase enzymes or extrusion at high temperature which results in dextrinization of starch (Mosha et al., 1983). Precooking of starch reduces the water holding capacity of the flour. These processes modify the starch structures, resulting in lower water binding properties, which can facilitate high energy concentration in gruels. Such preparations are expensive due to the high prices involved and are not affordable by households with low or average incomes in developing

countries. Alternative technologies should therefore be advanced to avail weaning diets of similar nutritional quality at affordable cost.

Ljungguist et al. (1987) investigated dietary bulk as a limiting factor for energy intake in millets among preschool children. They observed that diets with no millet malt added to them had higher paste viscosity and lower energy density, compared to those to which millet malt had been incorporated. They further observed that the paste viscosity limited the feed intake by the child per unit feed. It is therefore necessary to maintain low paste viscosity in gruels as well as high nutrient density in order for the child to get maximum nutrient benefit. Svanberg (1987) observed that consistency rather than the nutrient density of the gruel, determined the gruel intake in Ethiopian children. For cereal-based weaning food, both the nutrient density and gruel viscosity are important factors in the diet formulation. In gruels made from malted four, the hydrolysis of the starch take place during heating. The amylase enzymes generated during malting are mostly active at 60 – 70 °C. They reduce the viscosity of the gruel, making it possible to incorporate more flour solids hence more energy. The resultant gruel has a high calorie density per unit volume.

2.4 Potential Use of Malted Grains in Weaning Food Formulations

In Kenya malting of cereals is mainly done during preparations of local alcoholic beverages although in a few isolated cases such as in Bungoma and Busia districts, millet malts are being used to reduce the viscosity of the gruels meant for weaning purposes

(Personal Communication). The fingermillet malts are usually added to the high viscous cool gruels on warming after which the viscosity is reduced to an acceptable consistency.

During malting of cereals such as barley, Beta-amylase is biosynthesized to a greater extent than its counterpart, alpha-amylase. The alpha – amylase enzyme hydrolyses at random in the alpha-1-4, D-glycocidic linkages in polysaccharides. In the case of the Beta-amylase, the reaction proceeds from the non-reducing end of the linear polysaccharide chain by sequential release of maltose units. Consequently the branched amylopectin chain is not completely hydrolysed, since the two enzymes cannot hydrolyse the alpha-1-6 D-glucosidic bonds which are at the branching points of the amylopectin molecule. The resulting alpha-1-6 D-glucosidic bonds linked fragments constitute limit dextrins. Presence of any gluco-amylase would hydrolyse the alpha-1-6, and alpha-1-4, D-glycosidic bonds and hence reduce the limit dextrins and maltose to glucose.

Sorghums and millets have been shown to develop increased amylolytic activity after 48hours of germination (Mosha et al., 1983). Shukla et al. (1985) observed that the amylolytic activity generation in grains on malting was dependent on the nature of the grain. They observed that the enzyme activity was higher in the brown millet malts than in the white millet malts. Singh et al. (1984) also observed that corn malts had poorer amylase activity compared to wheat and barley. Cereal malts with high amylolytic activities are more effective in reducing paste viscosities of gruels.

Mosha et al, (1983) reported that a gruel of the same viscosity could be produced using at least three parts of malted sorghum flour or one part of the unmalted flour in the same volume of water. In this way, one could achieve high calorie density in gruels using malted flours.

Svanberg et al. (1987) also investigated the use of malted sorghum flours in reducing viscosity of gruels based on unmalted sorghum flours. They observed that 4% germinated sorghum flour was sufficient to achieve the necessary reduction of viscosity in such gruels. Malleshi et al. (1986) also observed that cereal malts can be used to reduce viscosity of conventional weaning foods or cereal legume blends during the slurry preparations. They reported that 2.55 barley malt flour or 0 15% fungal amylase reduced a 20% roller milled slurry from 5000 to 1000cp. These additions of the flour malts to the weaning food slurries has not been shown to affect the sensory acceptability or the shelf life of the foods (Desikachar, 1985; 1980a; 1980b).

2.5 Use of Amaranth as a Composite Flour

Several researchers have studied amaranth as a source of nutrient for complementing other foods. Such products consisting of amaranth-wheat and amaranth-corn composite flours at levels of 20% amaranth flour have been reported to give higher nutrient flours. (Lorenz, 1981; Sanchez-Marrowuin et al., 1986; Mugambi 1988)

Tover et al. (1982); Bressani et al. (1984);Sanchez-Marroquin (1985) and Pederson (1987) investigated the nutritive value changes when the protein from maize, wheat and rice flour were replaced with amaranth grain. The protein quality in the wheat and amaranth composite flour products improved with more amaranth flour. A complementary effect of the limiting amino acids lysine and threonine was achieved in the amaranth corn blend.

Pederson et al. (1987) studied the nutritive value of popped amaranth grain as a supplement for cereals blends of wheat, corn and low tannin sorghums. The amino acid scores were improved by the supplementation with amaranth. The improvement was greater for sorghum than for wheat and corn. Addition of amaranth alleviated the lysine and tryptophan deficiency in corn protein. Bressani (1988) recommended the use of whole grain amaranth as a food source, particularly as a weaning food, due to its excellent protein quality and relatively high energy content.

2.6 Summary of Literature Review

In summary it is evident that the nutritive values of sorghum and millets can adequately meet the daily recommended requirements of children if fed frequently enough (Appendix 1). The protein digestibility is however hampered by some antinutrient factors mainly tannins and phytic acid. These factors can in part be overcome by the use of malting and dehulling for sorghum and malting for fingermillet. Malting has the advantage of increasing the bioavailability of nutrients and was therefore further to be

investigated during this study. Since lysine is the limiting amino acid in the sorghums and millets, amaranth with a higher level of the lysine may be useful grain in complementing diets prepared for weaning children. The unsaturated fatty acids in amaranth could impart poor storage quality characteristics to the final product. This should be considered during formulation of weaning foods. It is therefore necessary to composite amaranth to minimum levels in order to prolong the storage quality of the final products.

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Source of Materials

3.1.1.1 Source of Sorghum, Millet and Amaranth

Brown sorghum *(Sorghum vulgare)* and fingermillet (*(Elusine coracana)* were obtained from the Dryland Research Station, Katumani in Machakos District. The most common sorghum varieties on local markets are *serena* and *seredo*. Pearl, finger and foxtail millets are also easily available.

The amaranth grain *Amaranthus hypochondriacus* (variety 1023) was obtained form the Field Station, University of Nairobi and from a farmer in Nyeri District in Kenya. All the experimental raw materials were tested for aflatoxin before experimentation.

3.1.1.2 Source of Enzymes

Porcine pepsin enzyme No. P7000 with an activity of 110,000 used during In Vitro Protein Digestibility was obtained from Sigma Chemicals Company. Amyloglucosidase No.7255 (glucoamylase-1-4glycan glucohdrolase E.C. No. 3:2:1:3) used for In Vitro Starch Digestibility was obtained from Sigma Chemicals Company.

3.1.1.3 Source of Vitamins and Minerals (Premix)

The minerals and vitamins were purchased as separate nutrients and blended during the experiment. The source of the premix was Alpha Chemicals Limited Nairobi and its composition is given in Appendices II and III.

3.1.1.4 Source of Rats

Weaning male Winstar rats of single strain 20 – 23 days old used during this study were obtained from the International Laboratory Research on Animal Diseases (ILRAD) Kenya.

3.1.2 Processing of Raw Materials

3.1.2.1 Cleaning

The purchased grains were aspirated to remove glumes, dust and foreign materials. They were washed in water and immediately dried in the sun to remove surface moisture.

3.1.2.2 Germination of Sorghum and Millets

The sorghum and millet grains were germinated according to a method used by Mosha et al (1983). The grains were washed and soaked in distilled water for 10 hours. The soaking water was then discarded, and the grain spread on perforated aluminium trays lined with cheese cloth to 1centimetre thickness. They were allowed to germinate at 25°C for 48 hours in a dark room. The grain was washed after 24 hours of germination to prevent mould growth. Germination process was arrested by drying the grain in a drying cabinet at 40°C to 10% moisture content.

3.1.2.3 Dehulling of Sorghum

Dehulling of sorghum was done using the TADD model 4E.220, Sennatt 0122C 058805 of Variable Machine Works Limited SASKA, Canada, available at the Department of Food Technology and Nutrition, University of Nairobi.

3.1.2.4 Milling of Grain

Milling of the grains for analysis was done on a cyclone sample mill (Udy Crop. Fort Collins, Co. Ltd) and milled to pass through a 0.5 mm screen.

3.1.3 Diet Preparation

The composite flours prepared according to the feed equation formula below were cooked into a stiff porridge (ugali) using a ratio of 1:3 of water of flour, cut to small

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pieces, and dried in an air drying cabinet at 60°C overnight. The samples were then milled in a hammer mill (Ndume ND. 20 Serial Number D2/1211) using sieve size 0.5mm. The flour was slightly moistened prior to feeding that rats to reduce the spillage.

3.1.3.1 Feed Equations

A formula expressed in the two equations below was used to calculate the quantities of each ingredient in the composite mixture, based on the protein requirement, composition of raw material and total quantity of feed required.

Equations without premix added:

PA/100 + PS or (M)/100 = 1.05 kg for 10kg feed (1)

A + S or (M) = X kg

Where P is the protein of amaranth, sorghum or millet. A, S and M are quantities in kg of amaranth, sorghum and millet respectively.

1.05kg is the minimum protein level in the feed, while X is the total quantity of feed in kg required for feeding.

Equations with 15% premix added:

PA/100 + PS (or (M)/100 = 1.05kg (1)

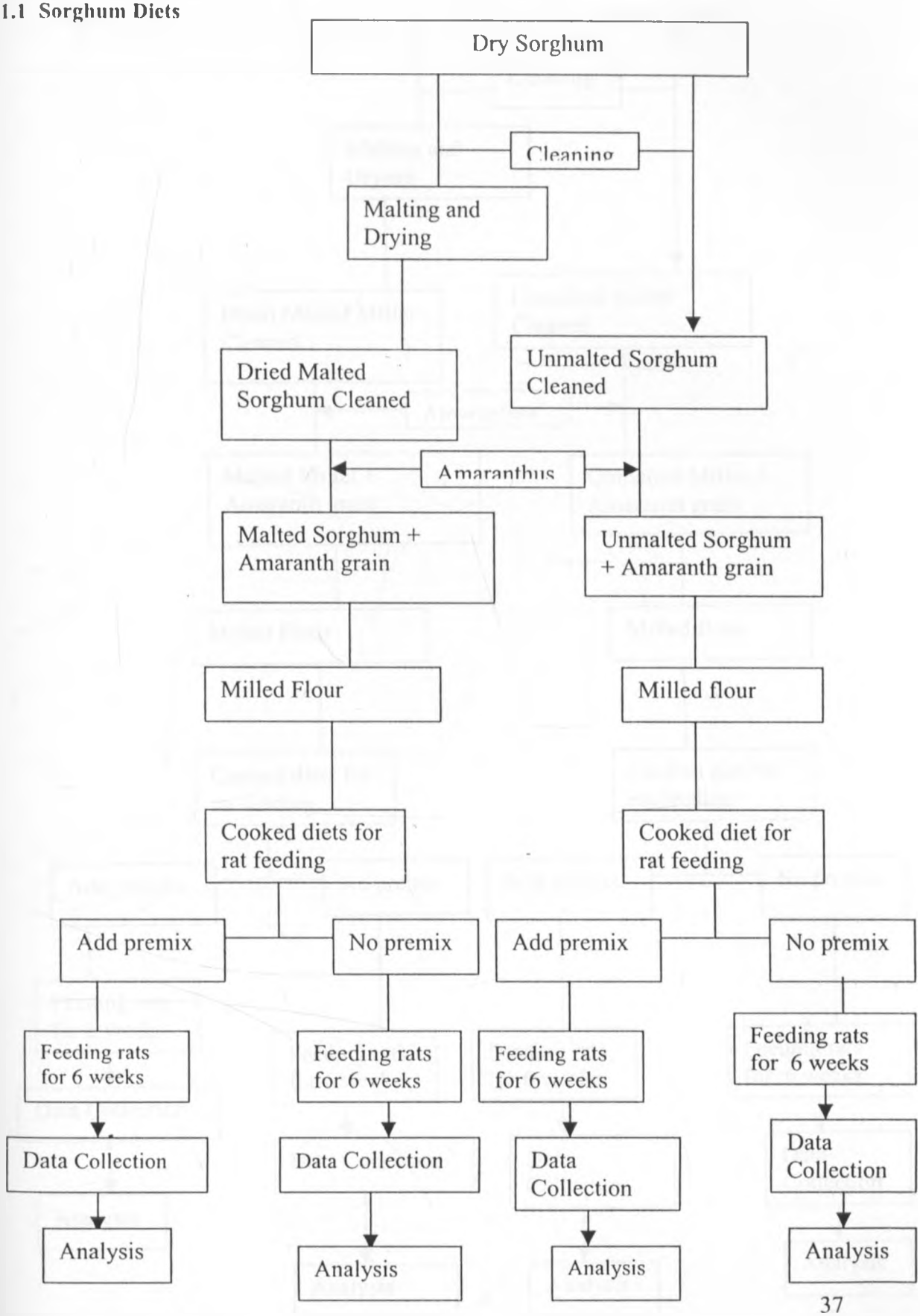
S + A = (X – Y)

Where Y = Quantity in kg of premix

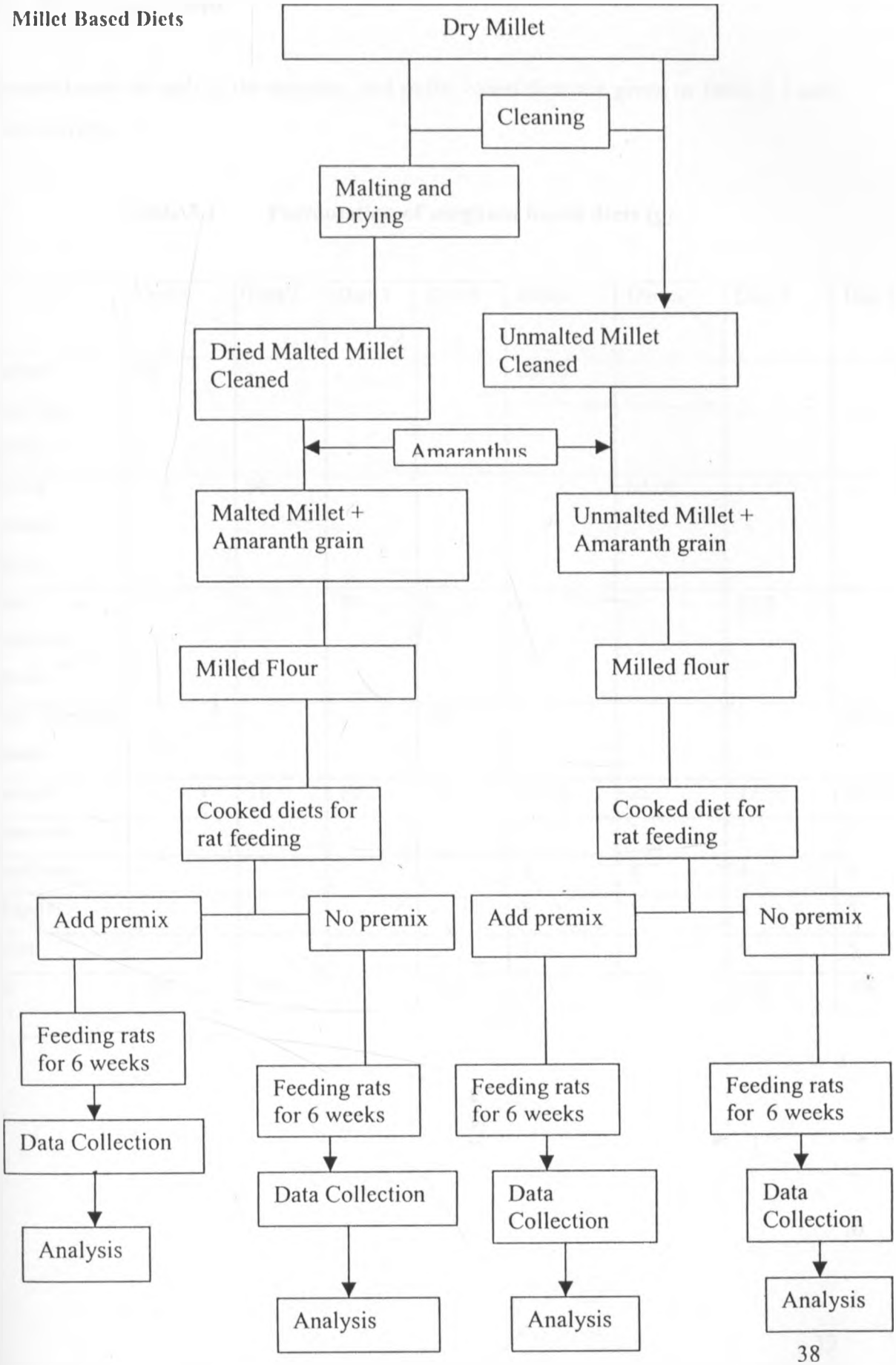
3.2 Methods

3.2.1 Experimental Designs

3.2.1.1 Sorghum Diets



3.2.1.3 Millet Based Diets



3.2.2 Diet Formulations

The constituents of each of the sorghum and millet based diets are given in Table 3.1 and 3.2 respectively.

Table 3.1 Formulation of sorghum based diets (g)

	Diet 1	Diet 2	Diet 3	Diet 4	Diet5	Diet 6	Diet 7	Diet 8
Unmalted Undehulled Sorghum	90	-	-	-	68.50	-	-	-
Dehulled Unmalted Sorghum	-	90	-	-	-	60.00	-	-
Malted Undehulled Sorghum	-	-	90	-	-	-	62.5	-
Malted Dehulled Sorghum	-	-	-	90	-	-	-	60.00
Amaranth	10	10	10	10	16.50	25	22.50	25.00
Vitamin mix	-	-	-	-	1	1	1	1
Mineral mix	-	-	-	-	4	4	4	4
Lord (oil)	-	-	-	-	5	5	5	5
Glucose	-	-	-	-	5	5	5	5
Total	100	100	100	100	100	100	100	100

Table 3.2: Formulation of fingermillet based diets (g)

	Diet I	Diet II	Diet III	Diet IV
Unmalted fingermillet	70	-	42.5	-
Malted fingemillet	-	70	-	42.5
Amaranth	30	30	42.5	42.5
Vitamin mix	-	-	1.0	1.0
Mineral mix	-	-	4.0	4.0
Lord (oil)	-	-	5.0	5.0
Glucose	-	-	5.0	5.0
Total	100g	100g	100g	100g

3.2.3 Analytical Methods

3.2.3.1 Determination of Moisture Content

The moisture content of the samples was determined gravimetrically according to Muller (1980). 2g of samples were weighed before and after drying to constant weight at 105oC in an air oven. Weight loss was expressed as percentage of the original weight to represent moisture content.

3.2.3.2 Determination of Ether Extract (%Fat)

The ether extract was determined according to the standard AOAC Soxhlet method 25.032 (1984). The weighed and dried flour sample was placed into a cellulose thimble and continuously extracted with petroleum either for about 16 hours. At the end of the extraction period, the ether was evaporated from the conical flask leaving an oily residue. The amount of fat was determined gravimetrically by weighing the conical flask before and after extraction.

3.2.3.3 Determination Of Crude Protein

This was determined by the standard AOAC Kjeldahl method 2.055 – 2.056 (AOAC, 1984).

About 0.5g of dried sample was accurately weighed and used for analysis in Kjeldahl flasks by boiling with concentrated sulphuric acid for 2-3 hours with selenium catalyst to increase the reaction. The digest that contained ammonium sulphate was cooled and transferred to the Kjeldahl distillation unit. 40% sodium hydroxide solution was added. The contents of the flask were heated to boiling. The ammonia which was distilled was collected in hydrochloric acid. The ammonia thus collected was estimated by acid titration since 1 litre of 1N HCL is equivalent to 17 NH_3 or 14gN.

3.2.3.4 Determination of Crude Fibre

The crude fibre was determined according to the standard AOAC method 7.066 – 7.070 (AOAC, 1984). 2g of the sample was boiled with 1.25 percent sulphuric acid for 30 minutes. After filtration the residue was rinsed with water several times before boiling in 1.25 percent sodium hydroxide for 30 minutes. The residue was rinsed, dried and ignited at 600oC for 30 minutes. The crude fibre was calculated as the difference in weight expressed as a percentage of the original weight.

3.2.3.5 Determination of Ash Content

Ash was determined by AOAC (1984) method 7.101. The total quantity of minerals in a sample was determined by ashing the sample first. The dried sample was placed in Muffle furnace and the temperature raised to 51.5°C for 4 hours.

3.2.3.6 Determination of Mineral Content

Analysis of the iron, calcium and phosphorous was carried out according to the standard atomic absorption spectrophotometric method 2.126 – 2.130 and 2.099 (AOAC, 1984).

3.2.3.7 Determination of Calorific Value

The calorific value of the samples was determined using the adiabatic bomb calorimeter (Model IKA KALORIMETER C400 adiabatic 2800 Bremen/FR). The gross heat of combustion was measured using water, and compared to the standard, where benzoic acid of known energy content is used.

3.2.3.8 Determination of Total Phenolic Compounds (Tannins)

The determination of the total phenolic compounds was done using the Folin Denis Method of 1912 for determination of tannins in forage crops. 500mg of dried ground sample was weighed into a 500ml Erlenmeryer flask, and about 350ml of water added. This was refluxed for 5 hours, cooled, diluted to 500ml, mixed well and left to stand.

2ml of the extract drawn from supernatant solution was used to determine the absorbance of the samples read in the spectrophotometer (Beckman Model 25). A standard curve for

transmittance or optical density, drawn against varying gallic acid concentrations was used to determine the quantity of tannins in the samples.

3.2.3.9 Determination of Calorie Density

Caloric density in the context of cereal porridges is mainly associated with the concentration of the carbohydrates. Since starch is the major carbohydrate in cereals and has the major influence on viscosity in porridges, viscosity as such can be used as an indirect measure of calorie density, therefore the calorie densities of the samples were determined by the viscosity method, according to Janse et al. (1961). The viscosity of the gruels at a consistency judged suitable for feeding an infant was 1,600 cps, when measured at 50 rpm. Plots of viscosity (cps) versus cereal flour concentration in gram sample per 100gm mixture were used to establish the concentration of the sample that would produce the reference viscosity of 1,600 cps. Ratios of water to flour were plotted to establish a reference curve. Caloric densities were calculated from this curve in kilocalories per 100ml. Proximate analysis and density data based on Atwater factors that are 5Kcal/g for protein and carbohydrate and 9 Kcal/g for fat were also calculated.

3.2.3.10 Determination of Particle Size Distribution in Flour

Prior to the determination of the particle size the grain was tempered to 14% moisture content using the formula which is used for wheat tempering as given below

Weight of water to be added = 100 – original Moisture Content

---------- X Weight of Sample

100 – desired Moisture Content

Particle size was determined by weighing the quantity of flour that was retained on different sieve sizes 0.5, 0.35, 0.25, 0.180 and a sieve size less than 0.180mm and expressed as a percentage of the total flour sieved.

3.2.3.11 Determination Of Water Holding Capacity Of Flour.

The absorption for all flour samples was determined by Centrifuge Method according to Sosulski (1978). About 5g sample of flour was adjusted to 54% moisture content and transferred into tared 50ml centrifuge tubes. 90ml of distilled water was added to each sample at the same time, washing down the inside of the centrifuge tube. The flour and water were vigorously mixed with a glass stirring rod for 30 seconds till all the flour was suspended. The suspension was allowed a 10 minutes rest while the flour on the side was scrubbed down with a glass rod. 10ml of distilled water was used to wash down the flour adhering to the stirring rod into the sample. The suspension was centrifuged at 2,300 rpm for 25 minutes. The supernatant was decanted and the centrifuge tube inverted at an angle of 15 - 20^0 in a forced draft air oven. The tube was allowed to drain and dry for 25 minutes at 50^0 C, cooled in a dessicator and weighed. Eight determinations were carried

out simultaneously. The percent water absorption was determined using the following equation.

% water absorption = (x + y – 5) 20

Where: x = increase in weight of flour in g

Y = "as is" weight of flour used in g

3.2.3.12 Determination Of Dehulling Qualities Of Sorghum

10g samples of sorghum (germinated and ungerminated) were dehulled with the TADD (Tengestial Abbrassive). Dehulling time was kept at one minute. Dehulled grains were stained with 0.25% methylene blue and o.75% eosin Y in 70% ethanol. The kernels were examined with a magnifying glass to evaluate the effectiveness of staining. The unstrained dehulled grains were first examined with the naked eye. After staining, if the pericarp was present, the grains appeared green while the germ was blue and starchy endosperm stained pink. The starch granules do not stain and the pink colour is due to the protein present.

3.2.3.13 Determination Of In Vitro Digestibility Of Starch (IVSD)

The In-Vitro Starch Digestibility of the fingermillets, sorghum and amaranth samples were determined by the phenol sulphuric acid method (Dubois et al., 1956). Flour samples were .defatted overnight in petroleum ether. 75mg of the defatted flour was placed in a 50ml conical flask and a few drops of dilute alcohol added to disperse the

entire flour. 10ml of distilled water was added and the flask covered with nitrogen free paper. The contents were autoclaved for 90 minutes at 19llbs at 121^0C for 2 hours in a water bath shaker. The contents were then made up to 250ml in a 250ml volumetric flask after incubation. 1ml of the contents was used to develop colour with 5% phenol and 96% sulphuric acid. The developed orange yellow colour was read at 490nm using a spectrophotometer after cooling. Standard glucose with concentrations varying from 10 – 50mg/100ml was used to determine the calibration was done concurrently with samples in order to determine the recovery of starch.

3.2.3.14 Determination Of In Vitro Protein Digestibility (IVPD)

In vitro digestibility assays were carried out according to Mertz et al. (1984) procedure, with slight modification. Samples were ground in a cyclone mill (Udy Comp. Fort Collins, Co.) using a 0.4mm screen. Cooking was achieved by mixing 200mg ground sample with approximately 2.0ml distilled water in a test tube, and heated for 20 minutes in a boiling water bath. After cooling, 200mg of uncooked sample was dispersed in 35.oml of 0.1M phosphate buffer (pH 2.0) containing 1.5mg pepsin/ml with activity 1200 unit per mg protein). The pepsin – sample mixtures were then incubated at 37^0C for 2 hours with continuous shaking. The suspensions were centrifuged at 4,800 x G at 4^0C for 20 minutes. The residue obtained following removal of supernatant was washed with 15ml of 0.1ml of 0.1M phosphate buffer (pH 7.0), followed by centrifugation as before. Again the supernatant was decanted and the residue once again washed on Whatman No. 3 filter paper in a Buchner funnel. The filter paper containing the undigested protein residue was folded, placed in digestion tube and dried in the over under vacuum for 2 hours at 80^0C.

The Nitrogen content of the supernatant pepsin digestion and the dried undigested pepsin residues were determined by a semi-automatic micro Kjeldahl technique (Technicon Autoanalyzer). Protein digestibility was calculated as a percentage of sample using the formula below:

$$\% \text{ Protein digestibility} = \frac{\text{Total sample \% P} - \text{Residual \% P} \times 100}{\text{Total sample P}}$$

% P = Percentage Protein.

IVPD was determined for all the raw materials used in weaning diet preparations and the final diets fed to the rats.

Standard statistical methods including analysis of variance (Snedecor and Cochran), and Duncan Multiple Range Test (Duncan, 1955) were used to analyse the experimental results.

3.2.3.15 Determination Of In Vivo Starch Digestibility (IVVSD)

This was determined by calculating the total amount of feed intake by rats over the fourth week and the total amount of faeces collected over the same period for each of the treatments.

A sample of each of the 8 faecal samples was analysed for the calorific value according to 3.37 and compared with the calorific value of the diet samples.

The in Vivo starch digestibility was calculated as follows:

Apparent starch digestibility = Calorific value of diet – Faecal Calorific value

----------X 100

Total N

3.2.3.16 Determination Of Protein Digestibility (IVVPD)

The same procedure as in 3.2.3.16 above was followed. The Microkjedhal analyzer was used for faecal protein determination. The apparent protein digestibility was calculated as follows:

Apparent protein digestibility = Total N intake – Faecal N x 100

Total N intake

3.3 Nutritional Evaluation By Protein Efficiency Ratio (PER)

The PER is defined as the gain in weight of test animals per gram of protein ingested.

PER = Gain in weight (g)

Protein intake (g)

The method used by Cambell (1963) was followed with a few modifications. Male winstar weaning rats were randomized for both cages and diets. The rats were divided into 12 groups of 6 rats each and housed individually in perforated metal cages. Each group was fed a particular diet slightly moistened to reduce spillage. All diets were fed at about 10.5% protein level. The diets and water were fed ad libitum. About 4 days were given for the rats to acclimatize to the diets. The feed intake and weight gain by rats were determined after every week for 4 weeks. During the fourth week all the faeces produced were collected in plastic bags over a period of one week. These were analysed for protein and calorific value in order to determine the digestibility of the diets. Rats were kept for one more week under observation.

3.4 Sensory Evaluation Of Porridge Made From Diets

Both the triangle test and hedonic scale sensory methods were used to assess the acceptability of porridge made from the sorghum and millet based diets. The premix was not included in the composite diet used for sensory evaluation. The porridge was prepared as in 3.2.3.10. Sixteen panelists were requested to assess the acceptability and indicate their preference for the porridge made. The triangle and hedonic scale sheets in appendix IV and V were used for the evaluation.

4. RESULTS AND DISCUSSION

4.1 Proximate Compositions of Sorghum and Amaranth Flours

4.1.1 Flour Moisture Content

The proximate composition of sorghum and amaranth flour samples are given in Table 4.1 below. The moisture content of the grains varied from 8.60% to 10.55% for amaranth and undehulled malted sorghum respectively.

Table: 4.1 Proximate Composition and Aflatoxin Content of Sorghum and Amaranth Flours Used in Diet Preparations.

	Source of Sorghum Flour				
Component in Percent	**Undehulled Unmalted Grain**	**Dehulled Unmalted Grain**	**Undehulled Malted Grain**	**Dehulled Malted Grain**	**Amaranth Flour**
Moisture	10.28	9.28	10.55	8.55	8.60
Ash	1.86	1.24	2.14	1.00	2.86
Crude Fibre	2.26	1.57	4.32	1.77	6.40
Protein	10.56	10.00	10.24	10.08	15.63
Crude Fat	3.41	2.54	3.27	1.72	7.45
Carbohydrate	69.73	70.81	69.48	65.63	58.98
Calcium*	279.38	270.20	279.26	260.21	570.41
Phosphorous*	160.33	152.48	160.38	140.38	280.26
Iron*	14.40	12.38	10.50	6.80	6.10
*Aflatoxin ppb	0.00	0.00	0.00	0.00	0.00

Average of duplicate samples
* mg/100g
* Aflatoxin of grain as quality control measure

4.1.2 Flour Crude Fibre and Ash Contents

The ash content of the undehulled sorghum was 1.86% while that of amaranth was 2.86%. The crude fibre content was 2.26% for undehulled sorghum and 6.40% for amaranth. Dehulling the sorghum grain reduced crude fibre and ash contents of the flour from 2.26 to 1.57 and 1.86 to 1.24% respectively. This was achieved through removal of the bran from the grain. Since the aleurone layer of the grain is high in mineral content, its partial removal would also reduce the ash content of the flour. This reduction in the fibre content is necessary for weaning food preparations. Malting undehulled sorghum significantly increased the crude fibre content from 1.86 to 2.14 percent as shown in table 4.1.

In call cases, amaranth flour had higher levels of ash and crude fibre. Amaranth would therefore raise the ash and fibre content in cereal composite flours where it is incorporated.

4.1.3 Flour Percent Protein

From table 4.1, the crude protein content of undehulled sorghum was 10.56% and was not significantly reduced on dehulling (10.0%) or malting (10.08%). Similar observations were made by Bhise (1986). Amaranth flour was found to have one and a half times as much protein (15.65%) as sorghum flour. Similar protein levels were reported by Saunders and Becker (1984). Blending the two has potential for higher protein quantity in composite flours.

4.1.4 Crude Fat Content in Flours

From table 4.1 the crude fat of undehulled sorghum was 3.41% and did not change on malting (3.27%). Amaranth flour had more than double as much crude fat as sorghum flour, 7.45% and 3.41% respectively. Hence compositing the two would produce a flour composite high in fat content and energy value. Whereas this would be beneficial nutritionally, it may reduce the shelf life of the flour, due to the presence of high levels of unsaturated fatty acids in the amaranth flour. The fat found in amaranth contains mainly oleic and linoleic acids (Teutonico, 1985). These fatty acids are essential for the body and so incorporation of amaranth in flour would be beneficial. Dehulling the sorghum flour reduced the fat content to 2.54%. Dehulling malted grain resulted in greater losses of crude fat than dehulling unmalted grain. This was attributed to starch damage during malting resulting in greater loss of the germ during dehulling.

4.1.5 Carbohydrates in Flours

The carbohydrate content is sorghum was 69.73% and did not change with dehulling. Malting the sorghum grain did not affect the grain carbohydrate content significantly. Dehulling malted grain led to loss of endosperm in the bran and hence reduced the carbohydrate content. The carbohydrate content in amaranthus was 58.98%.

4.1.6 Mineral Content in Flours

There are several minerals present in sorghum and amaranthus flours. The calcium, phosphorous and iron contents were similar to those observed by other scientists. Amaranth flour had on average twice as much calcium (570.41 mg/100g) as the sorghum

flours. The calcium level of sorghum flour was 279.38 mg/100g. The phosphorus content of the sorghum flours was 160.33 mg/100g. Compositing amaranth with sorghum flours could increase levels of calcium and phosphorus in the flours which is desirable for weaning foods. Amaranth flour had much less iron (6.10mg/100g) compared to sorghum flour (14.40 mg/100g).

Dehulling slightly reduced, the mineral content of the sorghum flours from 279.38mg/100g to 270.28mg/100g for Calcium, 160.33mg/100g to 152.48mg/100g for phosphorus and 14.40mg/100g to 12.38mg/100g for iron. The reductions were however insignificant. Malting did not have a significant reduction in the percent calcium and phosphorus in the grains. The iron was however reduced during malting. It is possible that iron is more translocated into the radicles during germination, and hence lost that way.

4.2 Flour Percent Water Holding Capacities (WHC)

For weaning foods, the behaviour of starch on cooking is very important since it determines the water holding capacity of the final flour. The more water held, the less the amounts of solids incorporated in the final product (high dietary density). The Water Holding Capacity (WHC) of the sorghum flour is given in Table 4.2. Unmalted sorghum flour was characterized by its high water holding capacity of 110.20%. On dehulling the WHC of sorghum reduced to 98.38% while on malting it reduced to 86.06%.

The high water holding capacity of unmalted sorghum flour is attributed to the chemically unchanged condition of the starch grain components, and especially the starch granules, which are known to have higher water binding capacity in their native form (Brandzaeg, 1979). One would expect reduction of water holding capacity of flour on germination of sorghum since amylolytic enzymes released during germination hydrolyse starch into sugars (Shukla, 1985). Abdialla et al. (1987) observed WHC of 79.16% for malted sorghum flour and 89.16% for pearl millet respectively. Variations would be expected since grains vary in their malting quality.

The reduction in WHC during dehulling could be combination of dehulling and malting that resulted in a greater reduction of flour water holding capacity as shown in the Table 4.2.

Reduced WHC is desirable in weaning diets because the starch will not swell much on cooking and will solubilize to a greater extent as more starch fragments are released into the slurry. This means that more flour will be incorporated into water to achieve any required slurry consistency. The calorific density will be subsequently increased as more flour is used.

The water holding capacity of amaranth flour was 112.75%. It was similar to that of undehulled and unmalted sorghum grain flours. Mixing of native sorghum and amaranth flours would therefore not change significantly the water holding capacity of the composite flours.

Table 4.2: Percent water Holding Capacities and the Energy Values of Sorghum and Amaranth Flours.

Flour Description	% Water Holding Capacity (WHC)	Energy value at viscosity 1600cp KJ
Unmalted undehulled Sorghum flour	110.20[a]	114.38[a]
Dehulled unmalted sorghum flour	98.38[b]	114.38[a]
Malted undehulled sorghum flour	86.06[c]	126.06[b]
Malted dehulled sorghum flour	78.34[d]	126.60[b]
Amaranth	112.75[a]	108.68[a]

Significance at $P < 0.05$
Mean values with the same letters indicate no significant difference between the means.

4.3 Caloric Density of the Porridge made from Flour

The calorific density of the porridge made from various flours are given in table 4.2. From the table, dehulling alone did not reduce the energy content of the flour. The energy values of the malted sorghum (126.06) flour porridge was significantly higher than that of the undehulled sorghum (114.38 KJ) and amaranth (108.68 KJ) respectively. Proportionately greater quantities of malted flour of 7% solids compared to native or unmalted dehulled flour of 5.5% solids suspension was used. The increase in flour solids in the malted flour porridge at a specified viscosity of 1600 centipoises accounts for the increased energy content.

Amaranth flour had the lowest energy level which is due to the low level of carbohydrates (58.98%). This difference of 5.70 KJ between the amaranth, native sorghum and unmalted dehulled sorghum flours was however not significant. The difference of 19.92 KJ between amaranth and malted sorghum flours was however significant. Composite flour involving amaranth and malted sorghum flours therefore reduced the total energy of the composite flour, although the protein level was improved.

Although germination of the sorghum grain is advantageous in increasing the energy content porridge slurries at specified viscosity level, extended germination reduces the dry matter content of the grain, and can lower the energy content. It means therefore that the period of malting should be controlled to 48 hours as recommended by Bhise et al. (1986). This allowed some amylolytic activity and reduced the water holding capacity of the flour.

4.4 Particle Size Distribution (PSD) in Sorghum and Amaranth Flours.

The results of the flour particle size distribution are given in Table 4.3. Of the total percent flour particles that passed through the 0.355 mm sieve, amaranth flour had significantly higher particle (71.57%) flours. The malted sorghum flour had a higher percentage of finer flour particles (63.72%) than the unmalted sorghum (51.88%).

4.5 Viscosity of Sorghum and Amaranth Flours

The results of the viscosities of gelatinized sorghum and amaranth flours at various solid concentrations are given in Figure 4.1. Viscosities 1, 2 and 3 represent amaranth, malted sorghum and dehulled sorghum flours respectively. It is evident that for all the flour slurries, the viscosity increased with increase in solid concentration with reference to a standard viscosity of 1600 cp for weaning porridge. 5.5% unmalted/undehulled sorghum and 7% malted sorghum solids respectively could be incorporated into the porridge.

Fig.4.1 Viscosity of sorghum and amaranth flour pastes as a function of percent flour content

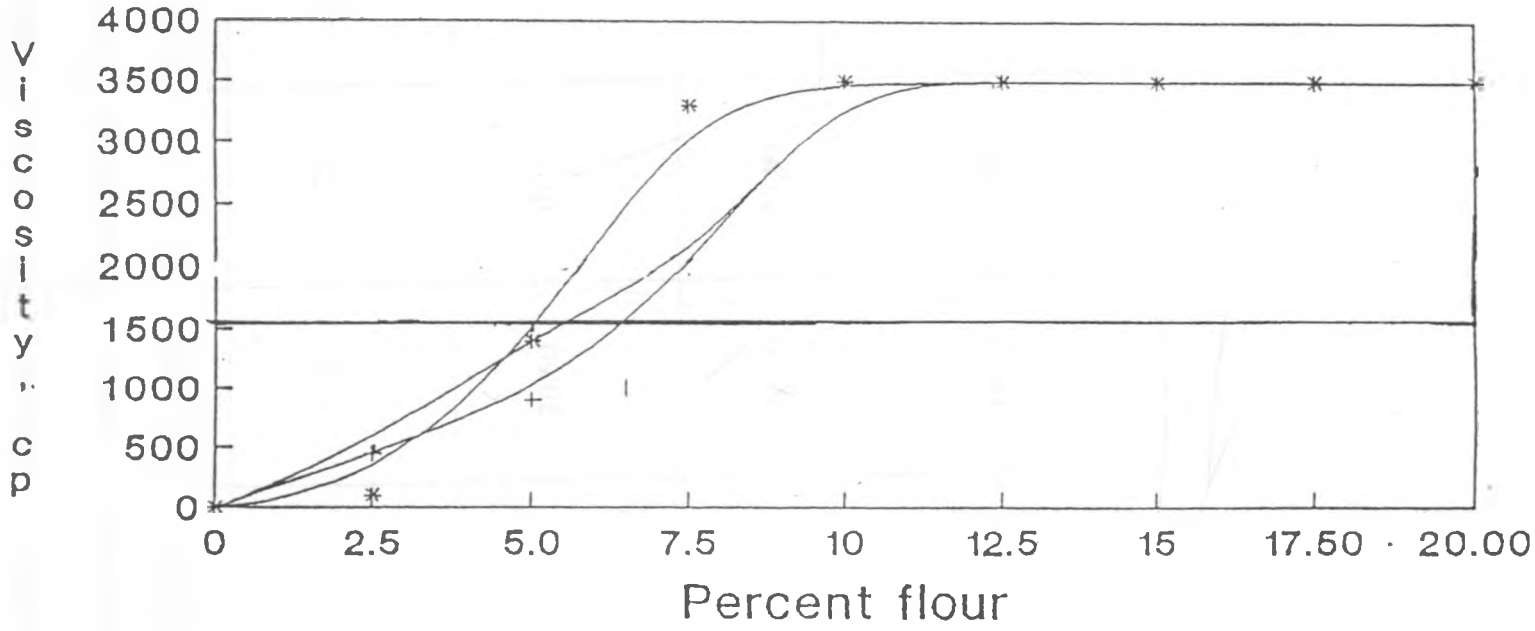


Table 4.3: Percent Flour Particle Size Passing Through Specified Sieves

Sieve Size (mm)	Unmalted Undehulled Sorghum	Dehulled Unmalted Sorghum	Germinated Undehulled Sorghum	Dehulled Germinated Sorghum	Amaranthus
<0.18	5.87	5.38	5.75	6.75	20.20
0.18	18.33	20.50	30.00	24.75	22.17
0.25	27.68	32.06	27.97	27.0	29.20
0.35	16.26	18.77	9.38	9.28	15.20
0.50	31.86	23.24	23.90	26.92	13.40

The viscosities of conventional foods are 1000 to 2500 cp for 1 – 3 year children (Mosha et at., 1987). Such viscosities are easily achieved by the sorghum and amaranth flours on gelatinization at very low solid concentrations.

Malting of sorghum for 48 hours had no observed effect on the concentration/viscosity relationship. The amylolytic activity obviously develops more slowly in the high tannin sorghum variety. The explanation for this may be the inhibiting effect exerted by the tannins to the activity of amylolytic enzymes in the seed. Sorghum may need to be germinated for more than 48 hours in order to achieve high amylolytic activity that will reduce the viscosity.

4.6 Percent in Vitro Protein and Starch Digestibility of Samples(IVPD, IVSD)

Good weaning materials should have a high protein and starch digestibility to ensure nutrient availability to the child. The protein and starch digestibility of the flours was determined through In Vitro assessments. The results of the In Vitro Protein Digestibility (IVPD) and In Vitro Starch Digestibility (IVSP) are given in table 4.4 and their ANOVA in Appendix VIII.

From the table the IVPD of ungerminated sorghum flour was 55.00 ± 2.83%, that of dehulled sorghum flour was 57.60± 2.83 while that of germinated sorghum was 60.30±2.83. There was no significant ($p < 0.05$) difference between the IVPD of the

three flours. These values were highly significantly ($p<0.01$) different from the standard casein (86.20±2.83).

The amaranth IVPD was 74.6± 2.83 which was significantly different from the sorghum flours but also significantly ($p<0.05$) lower than that of the standard casein (86.2 ± 2.83). Evidently both sorghum and amaranth have lower IVPD than casein but the IVPD of amaranth is higher than sorghum.

Tannins have been known to inhibit the protein digestibility. Schaffert et al. (1974) had earlier reported that dehulling may not inhibited the activity of the any residual tannins. When dehulling, elimination of all the tannins is necessary. Amaranth flour with comparatively low tannin content (0.27%) had significantly higher IVPD (74.60%). The high IVPD is advantageous for composite weaning flour preparations.

There is some improvement in the digestibility in malted grain (60.30%) which is advantageous for weaning foods as the digestibility and the subsequent assimilation into the blood stream would be increased.

Table 4.4: In Vitro protein and Starch Percent Digestibility in Sorghum and Amaranth Flours.

Sample	%IVPD	%IVSD	%Tannins
Ungerminated Sorghum	55.00 ± 2.83 [a]	44.25 ± 2.35 [a]	1.68±0.17 [a]
Ungerminated Dehulled Sorghum	57.60 ±2.83 [a]	68.36 ±2.35 [b]	0.9 ± 0.17 [b]
Germinated Sorghum	60.30 ± 2.83 [ab]	72.59 ±2.35 [b]	1.20±0.17 [c]
Amaranth	74.6±2.83 [c]	70.31 ±2.35 [b]	0.27 ±0.17 [d]
Soluble Starch		88.91 ±2.35	
Casein	86.2[d] ±2.83		

Values with the same letter within the same column indicate that no significant difference was observed between them ($p<0.01$)

Duncan Multiple Range Test was used for testing of differences in means.

The low IVPD in the undehulled grain could be attributable to the tannin (1.68%) that may have reduced the enzyme digestibility by binding proteins and repressing the enzyme activity.

4.7 In Vivo Starch and Protein Digestibility

Rats were fed stiffened porridge cooked and dried in the oven using various flours composited from sorghum and amaranth. For six weeks. The In Vivo Starch and Protein Digestibilities were determined. The results for the In Vivo starch and protein digestibilities of sorghum/amaranth based diets are presented in Table 4.5 and their ANOVA is given in Appendix VIII.

It was observed that the Starch Digestibility of stiff porridge made from malted sorghum was 76.65%. The starch digestibility of stiff porridge made from unmalted sorghum was 60.80%. There was a highly significant ($P< 0.01$) difference between the 2 diets. Malting significantly modified the intrinsic structure of starch rendering it more digestible.

From table 4.4 the In Vitro Starch Digestibility (IVSD) of ungerminated sorghum was 44.25 ± 2.35 percent. The IVSD for dehulled sorghum and germinated sorghum was 68.36±2.35 and 72.59 ± 2.35 respectively. These values were significantly different $p< 0.05$ from that of the ungerminated sorghum.

There was no significant $p < 0.05$ difference between the IVSD of dehulled and germinated sorghum from the IVSD of amaranth flour (70.31±2.35). However, these were all lower than the IVSD of soluble starch (88.91 ± 2.35) the standard for IVSD assessments. Table 4.4 also gives the Tannin content of the flours. It is possible that the enzyme inhibition could be attributed to the presence of tannins in sorghum 1.68± 0.17.

Amaranth has a lower tannin 0.27 ± 0.17 percent compared to that of germinated sorghum 1.20 ± 0.17%. A high IVSD is a prerequisite for the preparation of composite weaning since it is the starch in the form of carbohydrates that supplies most of the energy requirements of the growing child. The higher the IVSD the better the weaning flour quality. The IVSD of sorghum can be improved by dehulling and malting prior to compositing. Compositing the flour with amaranth does not compromise the IVSD digestibility.

Table 4.5: Apparent In Vivo Starch and Protein Digestibility in Sorghum – Amaranth based Weaning Diets

Diet Description	Percent In Vivo Starch Digestibility	Percent In Vivo Protein Digestibility
Unmalted Undehulled Sorghum + Amaranth diet-	60.80 ±2.58 [a]	55.65 ±2.31 [a]
Unmalted Undehulled Sorghum + Amaranth diet+	67.27±2.53 [ab]	58.01±2.31 [ab]
Unmalted dehulled Sorghum + Amaranth diet -	68.08 ±2.53 [bc]	64.51±2.31 [bc]
Unmalted dehulled Sorghum +Amaranth diet-	70.38 ± 2.54 [bc]	58.01 ± 2.31 [ab]
Malted undehulled Sorghum + Amaranth diet -	76.65 ±2.53 [bc]	67.75±2.31 [acde]
Malted undehulled Sorghum + Amaranth diet +	80.31±2.53 [dc]	74.41±2.31 [e]
Malted dehulled Sorghum +Amaranth diet -	81.56 ±2.53 [c]	73.25±2.31 [ac]
Malted dehulled Sorghum + Amaranth diet +	85.62 ±2.54 [c]	73.25±2.31 [dc]

Values with the same letters within the same column indicate no significant difference ($P < 0.01$).
(-) - No Vitamin-mineral premix added
(+) - Vitamin and mineral premix added

The generation of amylases on malting could have further contributed to the increase in the starch digestibility observed in the malted stiff porridge diet. The amylases breakdown the starch to simpler sugars that can easily be assimilated by the animals. Hydrolytic activities by amylases generated during germination have been reported earlier by several researchers (Malleshi, et al., 1986).

Dehulling the sorghum similarly improved the starch digestibility (from 60.80 to 68.6%). This improvement of starch in sorghum after dehulling can be attributed to the partial removal of tannins which may inhibit amylases in the digestive system (Chibber et al., 1980). Improved Starch Digestibility on dehulling has been reported by Chavan et al (1979). The stiff porridge that were fortified with Vitamin and mineral premixes had insignificantly higher In Vivo Starch Digestibility of 67.27%, 70.38%, 80.31% and 85.62% as shown in the table.

The IVVSD for the unmalted undehulled sorghum diets was observed to be 55.65%.Axtell et al. (1981) on the other hand reported sorghum digestibility values between 85% to 90%. They also observed that rats are more efficient in sorghum protein digestion compared to infants. Both dehulling and malting increased significantly the IVVPD from 55.65% to 64.71% and 67.75% respectively. Combined processes of malting and dehulling (73.25%) had no significant improvement of IVVPD for the malted sorghum based diets (74.41%). However, there was a significant ($p<0.05$) difference (64.51%) for the dehulled sorghum.

4.8 Animal Feeding Studies

The results of the means of the feed intake and total weight gain of rats fed sorghum diets are given in Table 4.6 and their ANOVA ir Appendix X. The Least Mean Square of the feed intake of undehulled Sorghum and Amaranth based porridges was 34.84 ±0.18. This was not significantly ($P<0.05$) different when premix was added to the stiff porridge (36.74 ±0.19). Conversely, there was a difference between dehulled unmalted sorghum and amaranth based diets with added Vitamins and Minerals (65.54±0.18) and those with no vitamins and minerals added (51.86 ±0.19).

There was a highly significant ($p<0.01$) difference between weight gain of rats feeding the dehulled diets and the germinated. The rats feeding germinated diets had higher weight gain of 8.58 ± 0.48 compared to1.29 ±0.48 for ungerminated and 4.52 ±0.50 for the dehulled sorghum. The least gain in weight was observed during the first week while the highest gains were observed in the last week. The replicates did not show a significant difference.

The observed poor feed intake and subsequent weight gain of rats fed undehulled unmalted sorghum amaranth based stiff porridge could be attributed to the growth inhibitors such as tannins in sorghum and probably amaranth phytic acid in amaranth. The anti-nutrients may have bound proteins and minerals respectively and hence interfered with protein digestibility and absorption. Kadam et al. (1986) also observed depressed growth rate and feed intake in rats fed high tannin sorghum varieties. This low

intake could also be attributed to the unpalatability of the food. Tannins could contribute to the poor feed intake. This area needs further investigation.

Rats fed stiff porridge containing dehulled sorghum had higher feed intake than those that were feeding the undehulled food. The improved feed intake and weight gain could be attributed to the reduction in tannins and phytic acid on dehulling of grain. The reduced fibre and bitter taste associated with the presence of tannins could have contributed to the increased feed intake. Chibber et al (1980) reported that dehulling high tannin sorghum also increased their digestibility.

Table 4.6: Least Means Squares PER and Standard Errors for Feed Intake (g) and Weight Gains (g) of Sorghum Diets

Parameter	Least Mean Squares		PER
	Feed Intake	Weight Gain	
Total	72.05±0.65[b]	8.06±0.17[a]	
Unmalted Undehulled Sorghum + Amaranth diet -	34.84±0.18	1.29±0.48[b]	0.40
Unmalted Undehulled Sorghum + Amaranth diet +	36.94±0.19[c]	3.43±0.50[f]	0.99
Unmalted dehulled Sorghum + Amaranth diet -	51.86±0.19[c]	4.52±0.50[c]	0.94
Malted Undehulled Sorghum + Amaranth diet +	65.54±0.18[f]	6.46±0.48[g]	0.94
Malted Undehulled sorghum+ Amaranth diet -	65.10±0.18[d]	8.58±0.48[d]	1.43
Malted Undehulled Sorghum+ Amaranth diet +	101.55±0.18[g]	29.52±0.48[h]	3.14
Malted dehulled Sorghum + Amaranth diet -	93.50±0.19[e]	14.28±0.50[e]	1.60
Malted dehulled Sorghum + Amaranth diet +	127.45±0.18[h]	24.38±0.48[i]	2.04

The highly significant feed intake and weight gain observed in rats feeding malted stiff porridge could be attributed to the reduction in tannin and probably phytic acid during soaking and germination as reported by earlier workers (Branzaez, 1979). It has been observed that malting releases some complexed nutrients like calcium and phosphorous due to phytase activity (Reddy, 1978). This increases the minerals available to rats for growth. Malting also increased the water soluble protein, lysine, methionine and soluble sugar in sorghum all of which contribute to better nutrient value. Similar increases in minerals on germination were reported by Marero et al. (1988) who malted other cereals and legumes.

A combination of germination and dehulling could have resulted in increased palatable of foods therefore increased feed intake. This combination is desirable in improving the digestibility and feed intake of weaning diets.

The addition of Vitamin and Mineral premixes significantly increased both the feed intake and weight gain suggesting that some of the deficiency/inhibitory influences to growth could have been overcome with addition of premix. With the incorporation of the premix some glucose was added to the feed intake and therefore the energy and protein intake per unit feed consumed was increased. The premix could easily be assimilated into the rats giving faster growth. The presence of micro-nutrients such as phosphorous involved in the growth promotion could have contributed to the weight gain in the rats feeding on stiff porridge to which premix has been added.

The protein efficiency ratios (PER) were lower for the rats fed undehulled sorghum diets (0.40) than those fed dehulled sorghum (0.94) and those fed germinated sorghum (1.43). These values were increased with the addition of premix . Mertz et al. (1981) observed that dehulling alone did not improve the digestibility in sorghum since the residual tannins exerted a growth depressing characteristic. But when the dehulling was done after germination then the digestibility of the sorghum was improved. The malted and dehulled sorghum diets had high PER which could be attributed to the reduction in the tannins and improvement in bioavailability and digestibility. Similar observations were made with malted sorghum-cowpea weaning blends where the PER was 2.4 (Reddy, 1978). Incorporation of amaranth protein may have improved the utilization of diets fed to the rats. Amaranth having a good protein profile with 5% lysine compared with that of sorghum and millets (2.5-3%) (Senft, 1979) complements sorghum based diets which are limited in lysine. Cooked amaranth has been observed to induce very highly significant growth rates in rats (Bressani et al., 1988). All these attributes could have contributed to the observed results in the feed intake and weight gain in rats.

Regarding the sorghum porridge made from malted sorghum and amaranth, there was a very highly significant ($p<0.01$) difference between the feed intake by rats fed diets with premix added to them (101.55 ± 0.18) than those with no premix added (65.10±0.18). The general feed intake of the amaranth sorghum based porridge that contained premix were higher (127±18) compared to those without premix (93.50±18). Ranking the feed intake, the dehulled malted sorghum amaranth based stiff porridge, the malted sorghum

amaranth based stiff porridge had a better feed intake than the undehulled, unmalted stiff porridge diets. Similar observations were made for the diets to which premix was added.

4.9 Sensory Quality of Porridge from Sorghum Based Diets

Porridge made from sorghum, amaranth based flour mixture were tested for acceptability by panelists composed of undergraduate students at the Food Technology and Nutrition Department, university of Nairobi. The results of the sensory mean scores of the porridge characteristic are given in Table 4.6.

The results showed that there was an improvement in colour of the porridge that contained dehulled sorghum. The colour significantly influenced the overall mean acceptability of the porridge. The texture and the flavour of the porridge did not influence the acceptability of the porridge significantly.

These results may further imply that sorghum products intended for use in weaning diets should be dehulled in order to improve the colour and therefore the overall acceptability of the final product. Malting of sorghum does not significantly affect the overall taste of the final porridge.

Table 4.7: Mean Sensory Scores of Sorghum/Amaranth Porridge

Porridge description	Colour	Texture	Flavour	Overall
Unmalted Undehulled Sorghum + Amaranth diet	7.41	5.83	6.00	5.75
Unmalted dehulled Sorghum + Amaranth diet	8.08	5.08	6.08	6.66
Malted undehulled Sorghum + Amaranth diet	7.58	5.58	5.83	6.60
Malted dehulled sorghum + Amaranth diet	8.25	6.00	5.83	6.16
Mean	8.08^{a}	5.87^{b}	5.93^{b}	6.29^{b}

Duncan multiple Range Test
(Values with the same letter indicate no significant difference existing between them ($p<0.05$).

4. 10 Fingermillet and Amaranth

Table 4.8: Proximate Composition and Aflatoxin Contents of Fingermillet and Amaranth Flour

The proximate composition and the aflatoxin contents of fingermillet and amaranth flour are given in table 4.8.

Component Percent	Source of Flour		
	Ungerminated Fingermillet	Germinated Fingermillet	Amaranth
Moisture	10.62	12.00	8.60
Ash	2.29	3.28	2.86
Protein	8.15	8.00	15.63
Crude fat	3.55	3.08	7.45
Crude fibre	3.45	4.17	6.48
Carbohydrate	71.85	69.47	58.98
Calcium*	570.41	611.23	483.26
Phosphorous*	280.26	310.38	380.38
Iron*	6.10	7.90	15.42
Aflatoxins	0.00	0.00	0.00

*mg/100g

From the results it was observed that unmalted fingermillet contained 2.29% ash, 8.15% protein, 3.55% crude fat, 3.45% crude fibre and 71.85% carbohydrates. The mineral contents were 570.41mg/100g, 280.26mg/100g phosphorous and 6.10mg/100g iron. The composition of amaranth was discussed earlier in reference to table 4.1. Both amaranth and fingermillet were free of aflatoxins. Thus they were safe for rat consumption. Carbohydrates are not limiting in these grains and this is advantageous for weaning foods as they should have high energy values. Germination of fingermillet for 48hours did not significantly affect the carbohydrate content.

4.11 Percent Water Holding Capacity and Energy Value of Fingermillet and Amaranth flour.

The water holding capacity (WHC) of the fingermillet and the energy value of the fingermillet and amaranth flour are given in table 4.9.

The Water Holding and energy values of fingermillet flour were significantly ($p<0.05$) different. From table 4.9 it was observed that there was a significant decrease ($p<0.05$) in the water holding capacity of the fingermillet on malting from 79.9% to 70.34% for the unmalted and malted fingermillet respectively. This was attributed to the damaged starch on malting and grinding of the grain. The high energy value is desirable for increased energy density weaning foods.

Amaranth as earlier presented in Table 4.8 had a significantly ($p<0.01$) higher water holding capacity than fingermillet. That may be due to the large surface area of the former as it tends to have a large number of small particles and thus large surface area for binding more water. The large number of small particles is advantageous for the texture of weaning food. But the high WHC is undesirable because during gelatization the starch matrix increases the viscosity and reduces the energy content per unit volume of the porridge.

From Table 4.8 the malted fingermillet had significantly higher energy values (221.24KJ) at 1600cp than the unmalted fingermillet 127.75KJ and amaranth 108.60KJ. It is possible that on malting more solids were incorporated into the slurry in order to attain the standard viscosity. This is desirable for weaning food preparations. Amaranth viscosity increased at low energy values and would therefore need to be composited with a flour low in viscosity such as malted fingermillet in order for more solids to be incorporated and the high energy densities
required for weaning to be achieved.

With increase in solid matter, the energy content increased. Svanber (1987) observed that malting allows for increased incorporation of solid matter and therefore energy in fingermillet porridges. Although more flour can be incorporated in slurries on malting, the final taste and acceptability determines the quantity of flour that can be incorporated since both attributes have to be met for increased acceptability and consumption.

Table 4.9 Percent Water Holding Capacities and Energy Value (KJ) of Fingermillet and Amaranth Flour

Sample	% Water Holding Capacity (WHC	Energy Value (KJ) at Viscosity of 1600cp
Ungerminated Millet	76.96[a]	127.75
Germinated Millet	0.34[b]	221.24[b]
Amaranth	112.57[c]	108.00[c]
SE	+- 2.58	+- 2.19

Duncan Multiple Range Test
Different letters indicate samples that are significantly ($P<0.05$) different from each other

4.12 Particle Size Distribution (PSD) in Fingermillet Flour

The results of particle size distribution (PSD) for the fingermillet and amaranth flour are presented in Table 4.10.

The total percent particles passing through the 0.35mm sieve were 71.56%, 75.18% and 79.51% for amaranth, unmalted and malted fingermillet respectively. There was no significant ($p<0.05$) difference between PSD of the unmalted and malted fingermillet. This could be attributed to the soft floury endosperm in the fingermillet that tends to easily shatter on milling. These results indicate that all the grains had a high number of small particles (>70%) which is desirable for a good texture of the final weaning product. This also suggests that if the amaranth and fingermillet (malted or unmalted) are composited then there could be homogenous flour achieved with equal representative number of particles of either grain. It also implies that there would be a large surface area of damaged starch exposed to the heating medium and this may shorten the cooking time as gelatinization is achieved in a short while. This would lead to saving on cooking energy.

Table 4.10: Particle Size Distribution (PSD) in Fingermillet and Amaranth Flour

	% Flour Particle Size Passing Through		
Sieves Size (mm)	**Germinated Millet**	**Ungerminated Millet**	**Amaranth**
<0.18	41.02	39.51	20.27
0.18	19.33	17.52	22.17
0.25	19.16	18.15	29.12
0.35	12.40	16.42	15.20
0.50	8.09	8.40	13.40

LSD($p<0.05$)

4.13 Viscosity – Concentration Curves of Fingermillet and Amaranth Porridge

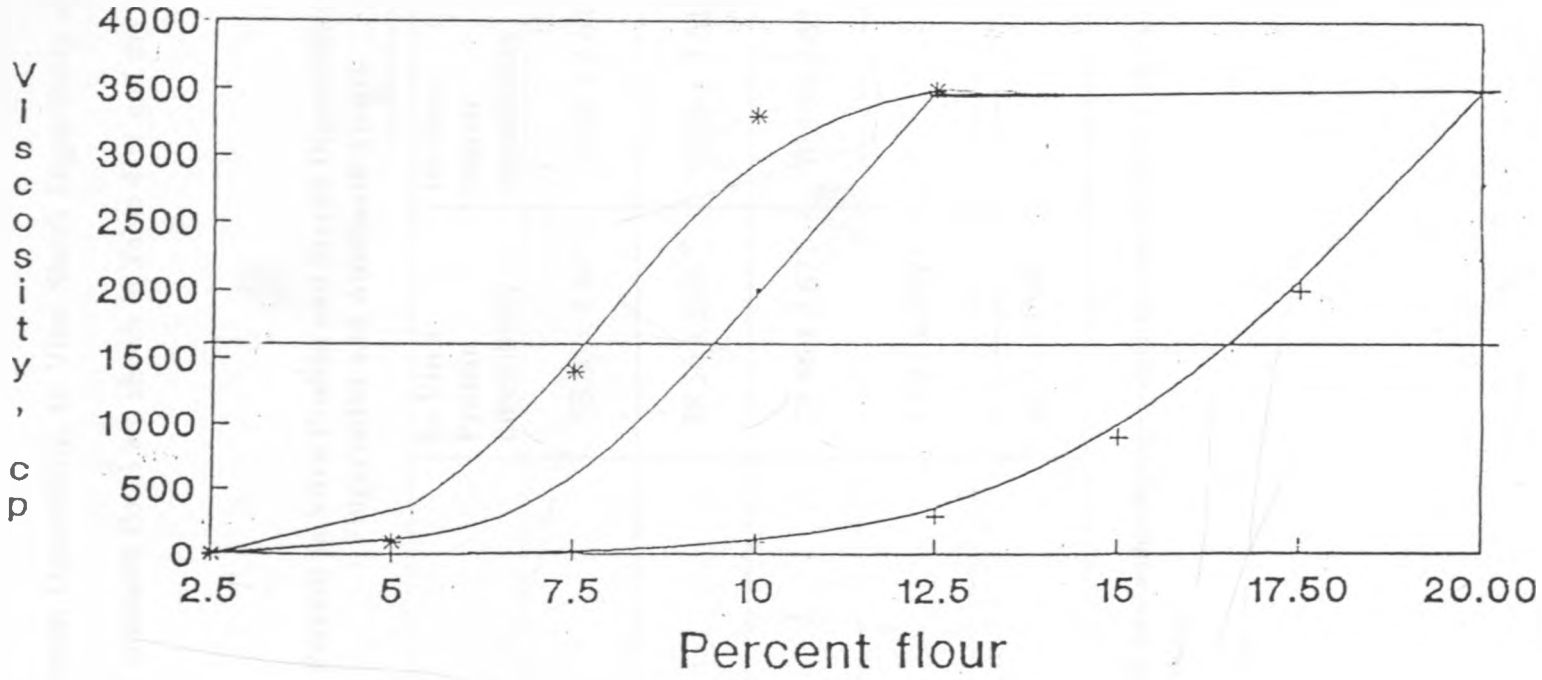
The change in viscosity with flour concentration in porridge is depicted in Figure 4.2. Curve 3 represents viscosity of porridge made from the unmalted millet, viscosity Curve 4, represents porridge made from the malted fingermillet flour and viscosity Curve 5 represents porridge made from amaranth. There was a significant ($p<0.05$) difference in the solids concentration of amaranth (7.5%) and the unmalted fingermillet (9.5%) at 1600cp standard viscosity. A highly significant ($p<0.01$) difference was observed between the solid concentration of the malted fingermillet (16.2%) at the same viscosity.

This suggested that amylase activity was developed to a large extent on malting fingermillet as shown by the large reduction in viscosity and increase in solid concentration. Similar observations were made by Desikachar (1980) when he compared the millet viscosity to that of maize and pearl millet. Brown fingermillet had earlier been observed to be superior in malting having a high amylase activity compared to white fingermillet varieties by Shukla et at. (1985).

The viscosity difference observed in the millet and amaranth flours could be attributed to the nature of the native starch. Amaranth starch was swelling more easily than fingermillet strands as indicated by the viscosity curve. The swelling ability of fingermillet starch decreased extensively on malting the grain necessitating incorporation of more flour in the porridge. As earlier observed, the consistency of porridge rather than

the energy plays a major role in the quantity consumed. The nature of the swelling power of the solids contribute to the final consistency of the final slurry. This is shown by the behavior of the curves on heating the porridge. Malted fingermillet could be suitable for reduction of high viscosity in weaning food. The high viscosity in amaranth can be reduced when the flour is blended with malted fingermillet. Such composites could be good for weaning flour preparation.

Fig.4.2. Viscosity of finger millet and amaranth as a function of percent flour content



4.14 The In Vitro Protein (IVPD) and Starch Digestibility (IVSD) of Fingermillet - and Amaranth Flours.

The In Vitro Protein Digestibility, In Vitro Starch Digestibility and tannin content for fingermillet and amaranth flours are shown in Table 4.11 and the ANOVA in Appendix XI.

Table 4.11 Percent In Vitro Protein and Starch Digestibility and Tannins in Fingermillet and Amaranth Flours

Sample Description	In Vitro Protein digestibility	In vitro Starch digestibility	%Tannin
Unmalted Fingermillet	58.80 ± 2.68 [a]	68.68 ± 2.62 [a]	0.31
Germinated Fingermillet	78.50 ± 2.66 [cb]	88.06 ± 2.61 [b]	0.21
Amaranth	75.66 ± 2.67 [b]	70.30 ± 2.62 [a]	0.058
Soluble Starch	84.07 ± 2.62 [b]		
Casein	85.21 ± 2.68 [c]		

Values with the same letter within the same column indicate that there is not significant($P < 0.05$) difference between them.

The germinated fingermillet and amaranth flours had high IVPD of 78.50 ± 2.66% and 75.66 ± 2.67% respectively. Compared to casein however, the IVPD for the three fingermillet samples were significantly ($p<0.05$) lower.

The higher IVPD observed in the malted fingermillet could be attributed to the hydrolysis of storage protein during germination. The hydrolysed proteins are easily digested by the pepsin enzyme and this could lead to the high IVPD. The observed IVPD are lower than those observed for fingermillet (78.10 – 85.1%) by Mertz et al. (1987). The difference could be attributed to the experimental condition and activity of the enzyme used. The decrease from 0.31% to 0.21% in tannin on germination of fingermillet was insignificant. The increased digestibility on malting is advantageous in the flour that is used for weaning food. Probably germination could be one of the processes used in preparation of fingermillet based weaning foods for improved digestibility.

Since the IVPD involves different sets of enzymes in the body, it is possible that the nutrients could not be adequately digested in the presence or absence of one enzyme and this could have contributed to the observed lower values. The knowledge of the digestibility of the grains is imperative and it is indicative of the way the nutrients break down and are digested prior to body absorption.

The percent IVSD of the malted fingermillet (88.06% ±2.61) was significantly different from that of the unmalted (68.68 ±2.62 and similar to that of soluble starch (86.07 ± 2.62). The high IVSD could be attributed to the presence of high levels of amylases

generated during malting as reported by Shuklar et al (1983). These amylases together with the *amyloglocosidase* hydrolyse the damaged starch to simple sugars and results in the high IVSD observed. Amaranth had significantly lower levels of percent IVSD (70.30 $\pm$ 2.62) than the malted and the soluble starch. This could be attributed to the lower levels of amylases present in amaranth.

The observed values for both IVPD and IVSD of ungerminated fingermillet could also be explained by the fact that the protein and starch digestibility in vivo involves many enzymes while during the In vitro experiment only one enzyme was involved.

4.15 In Vivo Digestibility of Starch (IVVSD) and Protein (IVVPD) in Millet and Amaranth.

The results of the IVVSD and IVVPD are presented in Table 4.10 and their ANOVA in Appendix VII.

Table 4.12 Percent In Vivo Protein and Starch Digestibility in Fingermillet-based Diets.

Stiff porridge constituents	In Vivo Protein	In Vivo % Starch Digestibility
(Unmalted Fingermillet + Amaranth)	64.68 ± 1.62 [a]	70.92[a]± 2.10 [a]
(Unmalted Fingermillet + Amaranth + Premix)	88.38 ± 1.61 [b]	88.38 ± 2.11 [b]
(Malted millet + Amaranth)	78.58 ± 1.62 [c]	82.89± 2.10 [c]
(malted Millet + Amaranth + Premix)	79.38± 1.62 [c]	84.66 ± 2.10 [c]

Duncan Multiple Range Test
Values with similar letter within the same column indicate that there is no significant ($P < 0.05$) difference

From table 4.12, the In Vivo Protein Digestibility of the stiff porridge made from ungerminated fingermillet-amaranth composite flour, was 64.68 ± 1.62%. This was significantly ($p<0.05$) increased to 78.58 ± 1.62% on malting and 88.38±1.62% on addition of premix. It may be hard to explain why there is significant increase on addition of premix. But it may be possible that the added premix contained micronutrients that facilitate increased absorption of the protein. Probably positive nutrient interaction and increased absorption in the presence of specific nutrients. This needs further research. Addition of premix did not significantly ($p<0.05$) affect the IVVPD of malted millet. Malting partially releases the protein digestive enzymes and this may have contributed to the observed values.

These results show that both malting and addition of premix increased the IVVPD. The increase is greater when the premix was added than fingermillet was germinated. It may therefore be inferred from these results that when premix is available, it should be used alone to improve weaning food. In the absence of premix, malting could improve the bioavailability to a available nutrients to some degree. Hence protein digestibility in fingermillet appeared to be limited by certain factors which were partially removed or inactivated by grain malting or addition of vitamin / mineral mix.

The In Vivo Starch Digestibility of the stiff porridge made from ungerminated fingermillet- amaranth composite flour was 70.92±2.10%. This was significantly increased to 82.89±2.11%. Addition of premix to the ungerminated amaranth composite significantly increased the IVSD to 88.38±2.11% while addition of the premix to the

germinated fingermillet–amaranth flour did not significantly ($p<0.05$) change the IVSD of the germinated flour.

The significant ($P < 0.05$) increase in the IVVSD was earlier observed for malted millet by Virupaksha et al. (1977). The increase could be attributed to the presence of digestive amylases that are generated during malting. These enzymes are generated to a greater extent in millets as earlier observed (Shuka et al, 1985). It is possible that addition of premix positively affects nutrient interactions leading to increased IVSD

4.16 Feed Intakes, weight gain and the Protein Efficiency Ratio (PER) of Rats fed on various diets.

The results of the means of the total feed intake, weight gain and PER of rats feeding on the fingermillet amaranth composite flour diets are given in table 4.13.

Table 4.13: The Least Mean Squares of the total feed Intake (g) Weight Gain (g) and PER of Rats on fingermillet –amaranth based diets

Diet Composite	Least Mean Square		Protein Efficiency Ratio
	Feed Intake	Weight Gain	
Unmalted Fingermillet + Amaranth	66.86 ± 2.3 [a]	10.08 ± 0.54 [a]	1.61
Malted Fingermillet + Amaranth	71.11 ± 2.7 [b]	13.04 ± 0.55 [b]	2.01
Unmalted Fingermillet + Amaranth + Premix	117.62 ± 2.7 [b]	39.65 ± 0.55 [c]	3.66
Malted Fingermillet + Amaranth + Premix	96.87 ± 2.2 [c]	25.38 ± 0.54 [d]	2.88

$$PER = \frac{\text{Weight gain}}{\text{Protein intake}}$$

Means bearing the same letters down the column indicate no significant ($P < 0.05$) difference.

The Least Mean Square of the feed intake of rats feeding on the ungerminated fingermillet amaranth based diet was 66.86 ±2.30. This was not significantly ($p<0.05$) different from the feed intake of rats fed germinated millet which was 71.11±2.70.

The observed values indicate no significant difference between the feed intake of the malted and unmalted fingermillet which would be attributed to the low tannin content in the fingermillet (0.008 – 0.31%). The observed similarity in feed intake between the feed intake of the malted and unmalted fingermillet was also reported by Hemalini et a. (1980) in rats fed on malted and unmalted fingermillet diets.

The reason for the insignificant reduction in feed intake in malted diets was not readily available but it appeared that in the absence of high tannin levels malting is not beneficial in improving palatability or texture of fingermillet/amaranth diets.

Addition of premix to both diets highly significantly ($p<0.01$)increased the feed intake for the ungerminated fingermillet amaranth composite to 117.62 ±2.70. The same trend was observed for the germinated fingermillet-amaranth based diet. The significant increase in feed intake on the addition of premix to the unmalted and malted fingermillet could be attributed to improved palatability and utilization of the diets. The diets with premix are easily digested into the blood stream and subsequently assimilated faster. During the study it was observed that there was a general increase in the amount of feed intake per week with the first week having the least intake and the last week the highest feed intake.

The weight gain of rats fed the ungerminated amaranth based diet was 10.08±0.54. There was a significant ($p<0.05$) increase on weight gain for the rats feeding the germinated fingermillet based diet to 13.04±0.55.

The significant increase in weight gain of rats in malted diets can be attributed to the improved protein digestibility on malting (Table 4.9). With increased digestibility the diet is easily assimilated into the body. Malting also increased bioavailability and this could have contributed to the observed stimulated growth that was better in the malted than unmalted millets.

There were no significant ($P < 0.05$) differences between the replicates indicating a fairly random distribution of rats on the diets. With addition of premix there was a highly significant ($p<0.01$) increase in weight gain for rats feeding the ungerminated (39.65±0.55) and the germinated diet (25.38±0.54). Similarly addition of premix also increased the weight gain to a higher extent than malting. The premix assimilation and subsequent utilization is better in diets that contain it than those where premix is lacking. The unmalted millet into which the premix is added gave higher weight gains than the malted diet implying that the unmalted millet is improved by addition of premix. It can be concluded that either malting or addition of premix can be used to improve the fingermillet amaranth based diets and resultant growth characteristics desirable in weaning foods.

The highest weight gain was observed during the fourth week while the least was observed during the first week.

The Protein Efficiency Ratio of rats feeding on the ungerminated millet-amaranth composite diets was 1.61. This was increased to 2.01 on malting. The increase was not significant. On addition of premix there was an increase in the PER for both the rats feeding the ungerminated fingermillet amaranth diets (3.66) and those feeding, germinated fingermillet amaranth diets (2.88).

There are several other nutrients from amaranth (Table 4.1) which could have enhanced the diets and therefore contributed to the observed PER values. From the results compositing of amaranth with fingermillet gave a product with high protein and growth potential.

Ifon (1980) observed a PER of 1.22 in a rat bioassay using malted fingermillet while Hemalini et al. (1980) observed a PER of 1.46. The difference between this and the observed value in this case 2.01 could be attributed to the presence of amaranth incorporated in the diet. The amaranth protein with a high lysine content of 5% compared to FAO/WHO standard of 5.5% Lysine improved the protein utilization in the diets and the difference between the PER could also be attributed to the higher protein feeding level of about 10.5% in the experiment compared to that of 8.5% for Ifon et al. (1980).

Incorporation of amaranth grain in fingermillet flours may be adequate to give the nutrients and growth required in rats. Malting may not be necessary. It may be that incorporation of higher levels of amaranth would give high growth rates. But this is an area needing further research. There could also be anti-nutrient factors in amaranth inhibiting digestibility in children. This study did not assay the anti-nutrient factors present in amaranth.

4.17 Sensory Evaluation of Fingermillet Based Diets.

The sensory evaluation of fingermillet-amaranth composite flour was undertaken by undergraduate students and the staff of the Food Technology and Nutrition Department University of Nairobi using a triangle test. The results of the hedonic scores are given in table 4.14. The triangle test carried out between the porridge made from malted and unmalted fingermillet flours indicated that there was a significant ($P< 0.05$) difference between acceptability of the two flours. Out of 16 panelists 14 were able to detect the difference. The 14 preferred the unmalted fingermillet flour to the malted. This could be attributed to the familiarity of the straight run unmalted fingermillet flour to the panelists. The malted porridge had high retro gradation (set back), took longer to cook to a smooth porridge and tended to form lumps on cooking which was undesirable. It was however observed to have a sweet aftertaste, and this could be attributed to the increase in sugar content on germination as earlier observed by Shukla et al. (1985). They observed an increase in soluble sugar 0.5 to 9.9 mg/100g for unmalted and malted fingermillet respectively.

It was concluded that millet porridge is most preferred in the unmalted form. Addition of amaranth changed the acceptability to an insignificant level. Germinated fingermillet was not very acceptable as a base for making porridge. Porridge made from malted millet flour may not be palatable to children. But it could be used as a source of amylases in smaller quantities to reduce the viscosity of the high bulk density foods used for making weaning foods.

Table 4.14: Mean Sensory Evaluation Scores of the Fingermillet Based Diets

	Ungerminated Millet	Germinated Millet	Ungerminated Millet plus amaranth	Germinated millet plus amaranth
Colour	4.56	3.40	3.60	3.50
Texture	4.43	3.03	3.00	3.20
Flavour	4.68	3.00	3.00	3.50
Overall	4.42	2.00	4.50	3.50
Mean	4.52^{a}	2.85^{b}	3.52^{a}	3.42^{a}

Duncan Multiple Test

5. CONCLUSIONS

From the research carried out, the following conclusions could be made:

a) It was possible to develop a weaning food using 90% sorghum and 10% amaranth. The protein in the flour was 14%. This level of compositing was probably the threshold level since it was not certain if the acceptability of the final porridge would change with increased amounts of amaranth.

b) Through the study it has was possible to establish a clear process for development of weaning foods entailing Water Holding Capacity, in vitro protein and starch digestibility, in vivo protein and starch digestibility and sensory evaluation. Knowledge of the aflatoxins levels and the viscosity of the flours was also important.

c) With malting of the sorghum for 48 hours it was possible to increase the amount of flour added to water to give a slurry of 1600 centipoise from 5.5% to 7%. Tannins in the grain limited to extent to which the digestibly of the germinated flour could be improved

d) The Particle Size Distribution of the sorghum, fingermillet and amaranth flours for both malted or unmalted produced a homogenous final product on milling which is a desirable for blending of the flours

e) The ant-nutrient factors in sorghum which are mainly tannins, were decreased by dehulling and malting of the grain prior to compositing it into weaning foods

f) The tannins in fingermillet are low and therefore growth depression was not significant.

g) The disadvantages of amaranth were noted to be high water holding capacity and presence of antinutrients which are undesirable for weaning food production. More research is needed to establish the latter in amaranth..

h) Addition of the premix to both unmalted and malted sorghum amaranth based diets had a significant effect on the feed intake and weight gain in rats. Therefore the premix if available should be added to diets to increase the bioavailability of essential micronutrients. However, in the absence of premix, then malting and dehulling should be undertaken for sorghum-based diets.

i) Malting did not improve the sensory acceptability of the sorghum based diets. The colour of the product was however improved on dehulling. The malted millet flours were not well accepted by panelists. Therefore malted fingermillet could be used as enzyme source in porridge preparation

j) The PER of malted and dehulled diets was higher than that of the unprocessed diets. This was increased with the addition of premix. Malted sorghum grain should be used in weaning foods because of its improved bioavailability and decreased antinutrients. To achieve the required consistency of porridge for weaning children sorghum should be malted for more than 48 hours dried and amaranth added prior to preparation of foods. Addition of amaranth to the sorghum and fingermillet flour improved their nutrient content.

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Appendix 1: Daily Average Energy Requirement and Safe Level Protein Intake for Infants and Children 3 Months – 5 Years Old.

Months	Wt.	Kcal/Kg	KJ/Kg	KJ/Day	Kcal/Day Intake		Protein
3 – 6	7.0	100	418	2300	700	1.85	13
6 – 9	8.5	95	397	1667	840	1.65	14
9 – 12	9.5	100	418	950	-	1.50	14
1 – 2Y	11	105	439	4800	1150	1.2	15.5
2 - 3Y.	13.5	100	418	5700	1350	1.15	15.5
3 – 5Y	16.5	95	397	6500	1550	1.10	17.5

Source: FAO/WHO (1988) Energy Protein Requirement pp. 17.
KJ = 4.2 Kcal.
Y=Years

Appendix II: Mineral Mix

Ingredient	%
$CaCo^3$	20.00
$K2HPO4$	22.83
$CaHPO4.2H20$	22.56
$Na2HPO.12H20$	11.74
$MgS04.7H20$	5.05
NaCl	7.66
Na lactate + 5H20	5.05
Ferric Citrate	1.96
KI	0.052
$MnS04.2H20$	0.020
$CuS04.5H20$	0.018
Zncl2	0.17
Starch	2.99

	100.00

1. Extracted from National Nutrition Research Institute (1959)
2. Soluble starch added as a filler.

Appendix III. Vitamin Mix

Ingredient	%
Riboflavin	0.030
Thiamine hydrochloride	0.025
Niacin	0.500
Pyrodoxine hydrochloride	0.125
Calcium pentothenate	0.200
Chlorine chloride	5.00
P-amino benzoic acid	1.500
Biotin	0.002
Folic acid	0.025
Vitamin B12	0.00125
Vitamin K	0.005
Ascorbic acid	0.500
Soluble starch	82.600

	100.00
	---

1. Extracted from National Nutrition Research Institute (1959).
2. Starch added as filler.

Appendix IV: Triangle Test Score Sheet
Organoleptic Evaluation of Fingermillet Diets

Date----------

SexM/F ----------

Product: Uji

1. You are given three samples one of them is different from the others. Please indicate the odd sample.

A
K

2. Which one of them do you prefere?

A.
K

Rate your preference using the scale below:

5. Like very much

4. Like moderately

3. Neither like nor dislike

2. Dislike slightly

1. Dislike very much

Give your remarks on any attribute

Thank you for your cooperation.

Appendix V. Score Sheet for Fingermillet Diets

Consumer Acceptability Trials

Date ----------

Sex M/F ----------

Product----------

Acceptability Rating Procedure

Here are 4 samples. Use the scale below to show your attitude by checking at the point that best describles your feeling about the sample.

	Score
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Di slike slightly	4
Di slike moderately	3
Dislike very much	2
Dislike extremely	1

Appendix V Cont'd

Score Card

Sample Code	Sensory Parameter			
	Colour Score	Texture Score	Flavour Score	Overall Score

General Comments

Signed ---

Appendix VI: Proximate Analysis of Sorghum Diets Fed to Experimental Animals: DM Basis

Sample	%Ash	%Fat	%Protein	% Crude Fibre
Unmalted undehulled sorghum + Amar	.2.01	3.64	9.34	2.99
Unmalted undehulled Sorghum + Premix	4.46	6.08	9.38	3.018
Unmalted dehulled Sorghum + Amar.	1.96	2.46	9.25	1.77
Unmalted dehulled sorghum + Amar. + Premix	4.17	6.62	9.20	2.40
Malted undehulled sorghum + Amar.	2.16	2.53	9.20	4.60
Malted undehulled sorghum + Amar. + Premix	4.08	8.39	9.21	3.49
Malted dehulled sorghum + Amar.	1.20	3.70	9.51	1.47
Malted dehulled sorghum + Amar. + Premix	4.28	7.24	9.38	1.63

Appendix VII: Proximate Analysis of Millet Diets Fed to Experimental Animals: DM Basis ; Rat Readings

Sample	%Ash	%Fat	%Protein	%Crude oil
Unmalted Fingermillet Plus amaranthus - premix	2.76	3.08	9.37	3.79
Unmalted Fingermillet + premix	5.13	8.02	9.10	3.60
Malted Fingermillet Plus amaranthus - premix	4.10	2.18	9.20	5.63
Malted Fingermillet Plus amaranth plus premix	5.13	6.88	9.10	4.00

Appendix VIII: ANOVA of IVSD and IVPD for sorghum samples

Sources of Variation	df	Mean Squares IVSD	IVPD
Treatments	4	542.02**	127.41*
Error	15	27.84	40.90
Total	19	569.86	168.31

* Significant P< 0.05
** Highly significant P< 0.01

Appendix IX: ANOVA and IVVPD of Sorghum Diets

Sources of Variation	df	Mean Square	
		IVVSD	IVVPD
Treatments	7	332.50**	217.41*
Error	24	52.96	42.92
Total	31	385.46	260.33

* Significant $P < 0.05$

** Highly significant $P < 0.01$

Appendix X; Analysis of Variance Table for the Feed Intake and the Weight Gains of Rats on Sorghum Diets.

Source	df	Least Square Means Feed Intake	Weight Gain
Treatments	7	2549.51**	2325.82**
Week	3	678.18**	154.76**
Replicates	5	24.89*	5.28
Remainder	176	8.06	5.65

Footnotes

** Highly significant ($P < 0.01$) difference
* Significant ($P < 0.05$) difference.

Appendix XI: ANOVA of IVSD and IVPD for Millet Samples

Sources of Variation	df	Mean Squares	
		IVSD	IVPD
Treatments	2	463.49	434.50**
Error	9	23.65	25.69
Total	11	487.14	460.19

Appendix XII: ANOVA of IVVSD and IVVPD for Millet Diets

Sources of Variation	df	Mean Squares	
		IVVSD	IVVPD
Treatments	3	229.16**	46.88**
Error	8	8.81	5.34
Total	11	237.97	52.22

Appendix XIII: Analysis of Variance Table for the Least Square Means of Feed Intake and Weight of Rats on Millet Diets.

Source	df	Least Square Means	
		Feed Intake	Weight Gain
Treatments	3	13071.15**	4215.67**
Week	3	5424.07**	227.05**
Replicates	5	293.83*	1.33
Remainder	84	117.89	7.00

Footnotes

** Highly significant ($P < 0.01$) difference
* Significant ($P < 0.05$) difference