THE EFFECT OF PROCESSING ON THE NUTRITIONAL VALUE OF FINGER MILLET (*ELEUSINE CORACANA*) SEED

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NOVEMBER, 2011

DECLARATION

I declare that the work in the thesis entitled “The effect of processing on the nutritional value of finger millet (*Eleusine coracana*) seed” has been performed by me. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

	_____	_____
Rotimi, Toyin Folasade	Signature	Date

CERTIFICATION

This Thesis entitled “THE EFFECT OF PROCESSING ON THE NUTRITIONAL VALUE OF FINGER MILLET (*ELEUSINE CORACANA*) SEED” by Rotimi, Toyin Folasade meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to the Almighty God, the creator of heaven and earth.

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My profound gratitude goes to God Almighty for his guidance and protection over my life.

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ABSTRACT

The effect of processing on the proximate composition, anti-nutrient levels and mineral contents of finger millet seed (*Eleusine coracana*) were analyzed. Diets containing processed finger millet seed (71.4g) per 100g feed were fed to four different groups of weaner rabbit for 56days. Animals' fed diet containing unprocessed finger millet seed were used as negative control group and animals' fed diet containing casein (standard protein) were used as positive control group respectively. Effect of processing methods like soaking, boiling, fermenting and roasting on the finger millet seeds significantly ($p<0.05$) reduced the anti-nutrient substances like tannins, saponins, phytate and oxalate when compared with their values from the unprocessed finger millet seed. Protein quality parameter's observed in the animals fed diet containing processed finger millet seeds like True Digestibity (TD), Biological Value (BV) and Net Protein Utilization (NPU) increased in the following order; Roasted finger millet seed (98.41±0.55, 54.85±2.23 and 54.26±2.48), Boiled finger millet seed (95.57±0.93, 52.88±0.96 and 50.13±0.97), Fermented finger millet seed (95.18±0.28, 52.52±1.81 and 49.97±1.67), and Soaked finger millet seed (94.52±0.55, 50.63±0.96 and 47.99±2.46). In conclusion, the results indicated that roasting treatment is the best processing method on finger millet seed for better utilization of its protein content, while fermentation is best in reducing the anti-nutrients contents.

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ABBREVATIONS

Symbols	Interpretation
%	percentage
g	grams
mg	milligrams
Kg	Kilograms
ml	milliliter
Cu	Copper
ATP	Adenosine triphosphate
LTD	Limited
^{o}C	degree centigrade
K_2SO_4	Potassium tetraoxosulphate (iv)
$CuSO_4$	Copper (II) tetraoxosulphate (iv)
W/V	Weight per Volume
V/V	volume per volume

CHAPTER 1

1.1 INTRODUCTION

Finger millet *(Eleusine coracana*), typically a tropical crop, belongs to the group of minor cereals. It is mainly consumed in India and Africa. It is an important cereal because of the excellent storage properties of the grain and the nutritive value, which is higher than that of rice and equal to that of wheat (Van Wyk and Gericke, 2000). It is also a good source of micronutrients like calcium, iron, phosphorus, zinc and potassium. Due to the presence of anti-nutrients in grains such as tannins and phytates, these micronutrients are less bioaccessable (Harris and Burns 1978).

Among millets, finger millet was reported to contain high amounts of tannins (Ramachandra *et al*., 1977), ranging from 0.04 to 3.47 per cent (cataechin equivalent). Poor iron availability (represented by low ionizable iron) in finger millets are due to their high tannin content which adversely affect the nutritional quality of the grains (Udayasekhara Rao and Deosthale, 1988). Tannins reduced apparently digestibility of protein and energy (Jansman *et al*., 1993). Cyanide readily and reversibly binds to a number of enzymes and proteins containing iron including haemoglobin, myoglobin, catalase and the cytochrome system (Ahmed *et al*., 1996; Uvere, *et al*., 2000).

Phytate interference with mineral absorption, especially calcium and zinc has been reported (Doherty *et al.*, 1982).

Oxalates affect calcium and magnesium metabolism (Oke, 1969), and react with protein to form complexes which have an inhibitory effect on peptic digestion (Oboh, 1986). Saponins act on the cardiovascular and nervous system as well as the digestive system (Gestener, *et a*l., 1966). Another anti-nutritional factor that affect the availability of some nutrients is phytate, a naturally occurring phosphorus compound which

significantly influences the functional and nutritional properties of foods. It is the main phosphorus store in mature seeds. Phytate has a strong binding capacity, readily forming complexes with multivalent cations and proteins.

Most of the metal complexes are insoluble at physiological pH. Hence, phytate binding renders several minerals biologically unavailable to animals and humans. However, these anti-nutrients can be removed by processing techniques such as; germination, soaking, roasting, fermentation, dehulling among others. Sankara Rao and Deosthale (1983) observed that malting of the grain reduced the phytin phosphorus in finger millet. This reduction was accompanied by significant increase in ionizable iron and soluble zinc, indicating the improved availability of these two elements.

1.2 STATEMENT OF RESEARCH PROBLEM

Bioavailability of some nutrients in food supplements prepared from finger millet seeds is severely limited by the presence of anti-nutrients such as tannins, phytates, oxalates, cyanides and saponins. (Gibbs-Russell *et al*., 1989).

1.3 JUSTIFICATION

The high cost of infant formulae has been a problem to poor people in our society. Hence the need for low cost ingredients that are nutritious and readily available. Processing methods like (boiling, soaking, roasting, fermenting.) that reduce the anti-nutrient content of the seed enhance biological availability of the nutrients and by extension the nutritional value of the seed.

1.4 GENERAL AIM AND OBJECTIVES

This work was undertaken to determine the effect of processing methods (soaking, boiling, roasting and fermenting) on the nutritional value of *Eleusine coracana* (finger millet seed).

1.4.1 Specific Objectives

i. To determine the proximate composition of raw and processed finger millet seed.

ii. To determine the concentration of the major mineral elements in the raw and processed finger millet seed.

iii. To determine the anti-nutrient content of raw and processed finger millet seed.

iv. To assess the nutritional quality of the raw and processed finger millet seeds by using various proportion of it on growth indices of weaner rabbits

v. To analyse the carcass characteristics of rabbits fed with unprocessed and processed finger millet seed.

CHAPTER 2

LITERATURE REVIEW

2.1 EFFECT OF PROCESSING ON NUTRITIVE VALUE OF FOODS

Nearly all foods, whether derived from plant or animal sources, are rarely fit for direct consumption and require some prior processing. Methods of food processing have been developed over the centuries and are adopted apparently to make the final product more attractive in flavour, appearance, taste, consistency, and so on. Besides these aspects of consumer preference, several of the methods aim at; making the food safe and wholesome, and conserving available food for later use by increasing its shelf or storage life (Udoessein and Ifon, 1992).The common practices of processing foods include; milling, germination or sprouting, malting, fermentation, soaking and cooking. Each of these processes qualitatively and/or quantitatively modifies the nutritive value of the food. Information on this aspect of food processing is important from both the nutritional and public health points of view.

Milling processing; in this food processing method the coarse fibrous bran or seed coat of the grain is removed, results in significant nutrient losses particularly of B-vitamins and minerals. The extent of the losses depends upon the degree of milling and the distribution pattern of nutrients in the grain. Although the nutrient content of food grains is relatively poor after milling, the bio-availability of certain nutrients appears to improve considerably. For example, the bio-availability of iron, as judged by the percentage of it present as an ionizable fraction was found to improve significantly by milling wheat to refined flour and decorticating chick pea (Prabhavathi and Narasinga Rao, 1979). Similarly in sorghum, the ionizable iron fraction increased from 18.6 to 28.7 per cent indicating a 40 per cent rise in the availability of iron (Sankara Rao and

Deosthale, 1980). Complex polysaccharides of the fibrous bran, polyphenolic compounds such as tannin and phytate are all known to limit the availability of iron (Hussain and Patwardhan 1959; Disler *et al*., 1975). Removal of these complex substances by milling partly explains the improved iron availability of milled grains

Germination or malting food processing method increases the vitamin C and folic acid content of food legumes and also degrades the anti-nutrients present in these food grains (Subramanian *et al*., 1976; Ismail *et al*., 1980). During germination several enzyme systems become active and bring about profound changes in the nutritive value of pulses (Subramanian *et al*., 1976; Ismail *et al*., 1980). Vitamin C, which is practically absent in dry legume seeds, increases in significant amounts after germination (De and Barai, 1949; Prabhavathi and Narasinga Rao, 1979). Similarly, Babu (1976) found two to threefold higher value for folic acid in the germinated grains than in the raw grains of the chick-pea and finger millet. On the other hand, it has been reported that anti-nutritional factors such as phytate, trypsin inhibitor, and haemaglutinins are broken down on germination (Subbulakshmi *et al*., 1976; Reddy *et al*., 1992). Phytate, which constitutes over 60 per cent of the total phosphorus in the raw grains of the Bengal gram, dropped to a level of 44 per cent in the 48-hour germinated grain with no change in total phosphorus (Prabhavathi and Narasinga Rao, 1979).

Cooking in boiling water or by steam pressure is yet another common practice of food processing. Apart from making food palatable and safe, cooking inactivates practically all the anti-nutritional factors that are heat labile (King et al,. 1985). Among the heat-stable factors in food legumes, tannins appear to leach out into the broth during cooking in water and thus the level in the grain is reduced to 30 per cent of the initial value (Udayasekhara Rao and Deosthale, 1988). Cooking also results in the loss of vitamins.

Studies reported by Raghunath and Belavady (1979a) have shown that cooking loss of riboflavin varies from 13 to 35 per cent in four pulses. On the other hand cooking losses of vitamin B_6 in these pulses were relatively low (13 per cent) and constant.

However, the availability of food iron is not altered by the cooking of rice and dhal, or by baking a phulka from whole wheat or flour. Cooking of food improves the biological value of its protein. Udayasekhara Rao and Belavady (1979) have shown that the growth performance of rats was better on cooked than on uncooked or raw diets based on different pulse and tuber proteins. Animals fed raw winged bean or its tuber failed to grow and showed a significant loss in body weight, and those fed on tubers even died. Improved growth responses to cooked diets were attributed to the destruction of the anti-nutritional factors present in these foods (Raghunath and Belavady 1979b). The utilization of protein is also influenced by the starches isolated from different sources, as shown by Nageswara Rao and Narasinga Rao (1978).

Parboiling of the grain is a suggested remedy to minimize the milling losses of thiamin, riboflavin, and niacin in the rice grain (Kik, 1957). During the parboiling process, water-soluble nutrients are driven from the outer layers into the inner layers of the grain and thus escape removal during milling. This beneficial effect of parboiling is observed also for chromium, molybdenum, and manganese (Deosthale *et al*., 1979).

Soaking is another good food processing method. Studies have shown that the most commonly consumed pulses, namely chick-pea, pigeon-pea, green gram and black gram; contain a significant amount of tannin that is mostly present in the seed coat. In overnight soaking 25-50 per cent of this tannin is lost, probably through leaching (Udayasekhara and Deosthale, 1988). Dissemination of this knowledge of the nutritional significance of the simple methods of food processing is important.

2. 2 *ELEUSINE CORACANA* PLANT

2. 2. 1 Botany of *Eleusine coracana*

Eleusine coracana belongs to the family of poaceae gramineae. Its common names are African finger millet, Ragi (India), bule (Zambia) Poho (Zimbabwe), Tamba (Hausa, Nigeria). *Eleusine coracana* is found in warm temperature regions of the world from Africa to Japan and also in Australia. It is present in archeological records of early African agriculture in Ethiopia and it is originated in Uganda (National Research Council, 1996).

It is an important staple crop in many parts of Africa. Before maize was introduced, it was the staple crop of the southern African region (Gibbs-Russell *et al*., 1989). *Eleusine coracana* is a tufted annual grass that grows to a height of 210-620mm tall. The leaf blades are shiny, strongly keeled and difficult to break and are 220-500mm long and 6-10mm wide. The leaves are typically green in colour. It has an exceptionally strong root system and it is difficult to pull out of the ground by hand (Van Wyk and Oudtshoorn , 1999).

2.2.2 Growing Finger Millet (*Eleusine coracana)*

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an important subsistence cereal in parts of Africa and south Asia. The species has two subspecies, *africana* and *coracana* (L.) Gaertn. Subspecies *africana* has two races, *africana* and *spontanea*, while subspecies *coracana* has four races: *elongata, plana, compacta* and *vulgaris* (Saraswat, 2004.).

Finger millet is mostly self-pollinating, with some amount of cross-pollination (1%) mediated by wind (Jansen and Ong 1996; Purseglove, 1972). Finger millet grows best in an environment with medium rainfall, an annual temperature range of 11 to 27°C and a

soil pH of 5.0 to 8.2 (Duke 1978, 1979). Areas with low precipitation and low relative humidity during seed ripening and maturation are best for regeneration. Carry out regeneration in the rainy season as finger millet requires moist conditions for germination. Finger millet cultivars are known to vary in time to maturity but ear heads can be harvested about 40 days after flowering to facilitate easy threshing.



Plate I. A View of *Eleusine coracana* Plant.



Plate II. *Eleusine coracana* seeds

2. 2. 3 Millets and Their Uses

Millet is a versatile grain that can be used in many different types of food. Millet is one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes (Jansen and Ong 1996). Millet has been used in Africa and India as a staple food for thousands of years and it was grown as early as 2700 BC in China where it was the prevalent grain before rice became the dominant staple. It is documented that the plant was also grown by the lake dwellers of Switzerland during the Stone Age (Saraswat, 2004).

Today, millet ranks as the sixth most important grain in the world, sustains 1/3 of the world's population and is a significant part of the diet in northern China, Japan, Manchuria and various areas of the former Soviet Union, Africa, India, and Egypt (Gopalan., et al 1992). Millet is a major crop in many of these countries, particularly Africa and the Indian subcontinent where the crop covers almost 100 million acres, and thrives in the hot dry climates that are not conducive to growing other grains such as wheat and rice (Smith, 1998). The Hunzas, who live in a remote area of the Himalayan foothills and are known for their excellent health and longevity also enjoy millet as a staple in their diet. Millet is used in various cultures in many diverse ways: The Hunza's use millet as a cereal, in soups, and for making dense, whole grain bread called *chapatti*. In India flat thin cakes called *roti* are often made from millet flour and used as the basis for meals (Ramachandra et al., 1970).

In Eastern Europe millet is used in porridge and kasha, or is fermented into a beverage and in Africa it is used to make bread, as baby food, and as *uji*, a thin gruel used as breakfast porridge. It is also used as a stuffing ingredient for cabbage rolls in some countries (Nyachoti et al., 1997). Millet was introduced to the U.S. in 1875, was grown

and consumed by the early colonists like corn, then fell into obscurity. At the present time the grain is widely known in the U.S. and other Western countries mainly as bird and cattle feed. Only in recent years has it begun to make a comeback and is now becoming a more commonly consumed grain in the Western part of the world (Gopalan et al., 1992). The plant is now grown in the U.S. on 200,000 acres in Colorado, North Dakota, and Nebraska, but much of the crop is still used for livestock, poultry, and bird feed. There are different types of millets which are described in this literature; Pearl millet, *Pennisetum glaucum*, is also known as spiked millet, bajra (in India) and bulrush millet (Purseglove, 1972). Pearl millet may be considered as a single species but it includes a number of cultivated races. It almost certainly originated in tropical western Africa, where the greatest number of both wild and cultivated forms occurs. About 2 000 years ago the crop was carried to eastern and central Africa and to India, where because of its excellent tolerance to drought it became established in the drier environments.

The height of the pearl millet plant may range from 0.5 to 4 m and the grain can be nearly white, pale yellow, brown, grey, slate blue or purple. The ovoid grains are about 3 to 4 mm long, much larger than those of other millets, and the 1 000-seed weight ranges from 2.5 to 14 g with a mean of 8 g. The size of the pearl millet kernel is about one-third that of sorghum. The relative proportion of germ to endosperm is higher than in sorghum.

Minor millets (also referred to as small millets) have received far less attention than sorghum in terms of cultivation and utilization. They include finger millet (*Eleusine coracana),* foxtail millet (*Setaria italica*), kodo millet (*Paspalum scrobiculatum),* common or prove millet (*Panicum miliaceum),* little millet (*Panicum sumatrense*) and

barnyard or sawa millet (*Echinochloa crus-galli* and *Echinochloa corona)* . More information is available on finger millet than on any of the others. Minor millets account for less than one percent of the food grains produced in the world today. Thus, they are not important in terms of world food production, but they are essential as food crops in their respective agro-ecosystems. They are mostly grown in marginal areas or under agricultural conditions where major cereals fail to give sustainable yields. Detailed descriptions of these millets are given by (Prasada- Rao et al., 1993).

Finger millet

Finger millet, *Eleusine coracana* L., is also known as African millet, koracan, ragi (India), wimbi (Swahili), bulo (Uganda) and telebun (the Sudan). It is an important staple food in parts of eastern and central Africa and India. It is the principal cereal grain in northern and parts of western Uganda and northeastern Zambia. The grains are malted for making beer. Finger millet can be stored for long periods without insect damage (Purseglove, 1972) and thus it can be important during famine. Numerous cultivars have been identified. In India and Africa, two groups are recognized: African highland types with grains enclosed within the florets; and Afro-Asiatic types with mature grains exposed outside the florets. It is believed that Uganda or a neighbouring region is the centre of origin of *E. coracana,* and it was introduced to India at a very early date, probably over 3000 years ago. Though finger millet is reported to have reached Europe at about the commencement of the Christian era, its utilization is restricted mostly to eastern Africa and India.(Jansen and Ong 1996).

The height of cultivars varies from 40 cm to I m and the spike length ranges from 3 to 13 cm. The colour of grains may vary from white through orange-red deep brown and

purple, to almost black. The grains are smaller than those of pearl millet, and the mean I 000-seed weight is about 2.6 g.

Foxtail millet

Foxtail millet, *Setaria italica* L., is also known as Italian, German Hungarian or Siberian millet. It is generally considered to have been domesticated in eastern Asia, where it has been cultivated since ancient times. The main production area is China, but *S. italicia* is the most important millet in Japan and is widely cultivated in India (Purseglove, 1972). It is believed to have been one of the five sacred plants of ancient China (from 2700 BC). Because of its short duration it is a suitable crop for growing by nomads, and it was probably brought to Europe in this way during the Stone Age, as seeds abound in the Lake Dwellings in Europe.

The height of the plants varies from 1 to 1.5 m and the colour of the grain varies from pale yellow, through orange, red and brown to black. The 1000-seed weight is about 2g.

Common millet

Common millet, *Panicum miliaceum* L., is also known as prove millet, hog millet, broom-corn millet, Russian millet and brown corn. This millet is of ancient cultivation. It is the milium of the Romans and the true millet of history. It was cultivated by the early Lake Dwellers in Europe. It is believed to have been domesticated in central and eastern Asia and because of its ability to mature quickly was often grown by nomads. The shallow-rooted plant varies in height between 30 and 100 cm. The grain contains a comparatively high percentage of indigestible fibre because the seeds are enclosed in the hulls and are difficult to remove by conventional milling processes. The 1000-seed weight is about 5 g (varying between 4.7 and 7.2 g). Common millet is particularly

suited to dry continental conditions and grows in more temperate climates than other millets.

Little millet Little millet, *Panicum sumatrense* Roth ex Roemer and Schultes, is grown throughout India to a limited extent up to altitudes of 2 100 m but is of little importance elsewhere. It has received comparatively little attention from plant breeders. The plant varies in height between 30 and 90 cm and its oblong panicle varies in length between 14 and 40 cm. The seeds of little millet are smaller than those of common millet.

Barnyard millet

Barnyard, Japanese barnyard or sawa millet [*Echinochloa crus-galli* (L.) P.B. and *Echinochloa colona* (L.) is the fastest growing of all millets and produces a crop in six weeks. It is grown in India, Japan and China as a substitute for rice when the paddy fails (Purseglove, 1972). It is grown as a forage crop in the United States and can produce as many as eight harvests per year. The plant has attracted some attention as a fodder in the United States and Japan. The height of the plant varies between 50 and 100 cm.

Kodo millet

Kodo millet, *Paspalum scrobiculatum* L., is a minor grain crop in India but is of great importance in the Deccan Plateau. Its cultivation in India is generally confined to Gujarat, Karnataka and parts of Tamil Nadu. It is classified into the groups Haria, Choudharia, Kodra and Haria-Choudharia depending on panicle characters. Kodo is an annual tufted grass that grows to 90 cm high. Some forms have been reported to be poisonous to humans and animals, possibly because of a fungus infecting the grain. The

grain is enclosed in hard, corneous, persistent husks that are difficult to remove. The grain may vary in colour from light red to dark grey (Gopalan et al., 1992).

Research results so far on finger millet are promising, showing the grain to have great aptitude and versatility and more and more uses for millet are being discovered every year, including its potential benefits in the American diet (Smith, 1998). Millet is superior feed for poultry, swine, fish, and livestock and, as it is being proven, for humans as well (Nyachoti *et al.*,1997).

Finger millet is eaten by grinding the grains up for porridge, or as in Indonesia, eaten as a vegetable; sometimes it is ground into flour and used for bread or various other baked products. The seeds are nutritious and easily digestible by infants and the elderly (National Research Council, 1996). In southern parts of India, pediatricians recommend finger-millet based food for infants of six months and above because of its high nutrient content especially iron and calcium (Dandrea *et al.*, 1999). The grain may be left to germinate to make malt which is very popular in southern Africa due to the sweetness of the malt (Van Wyk and Gericke, 2000). Its ability to convert starch to sugar is surpassed only by barley (National Research Council, 1996). The leaf juice has been given to women in childbirth and the plant is diuretic (Watt et al., 1962). Finger millet seed is used in traditional medicine as an internal remedy for leprosy or liver disease (Van Wyk and Gericke, 2000) as well as in measles, pneumonia and small pox (Duke and Wain, 1981). *Eleusine coracana* is especially valuable as it contains the amino acid methionine, which is lacking in the diets of hundreds of millions of the poor who live on starchy staples such as cassava, plantain, polished rice or maize meal (Dandrea *et al.*, 1999).

2. 3 CHEMICAL COMPOSITION OF *ELEUSINE CORACANA* SEED

2. 3. 1 Proximate Composition

In finger millet, the proximate composition was reported as protein 5.8% to 12.8%, fat 1.3 to 2.7 percent, total ash 2.1 to 3.7 percent and carbohydrate 81.3 to 89.4 percent (Hulse *et al.,* 1980). Dandrea *et al* (1999) reported the nutritive value of *Eleusine coracana* per 100g as protein 7.3g, fat: 1.3g, carbohydrate 72g, mineral 2.7g, calcium 344mg, fibre 3.6g, and energy 328kcal. United States National Research Council, National Academy of Science (1984) reported that the nutrient composition of *Eleusine coracana* per 100g were; protein 7.7g, fat 1.5g, Ash 2.6g, fibre 3.6g Carbohydrate 72.6g, Energy 336kcal, calcium 350mg, iron 3.9mg, phosphorus 320mg, magnesium 137mg, zinc 2.3mg, and Cu=0.47mg.

There are variations in these values when compared with the values obtained in Table4.2 due to geographical differences.

2. 3. 2 Anti-Nutritional Factors

It has been known that seeds generally contain a wide range of substances, which, if not destroyed or removed, will have an adverse effect on their nutritional value (Udoessein and Ifon, 1992).

2. 3. 2.1 Tannins

Eleusine coracana is a good source of mirconutrients like calcium, iron, phosphorus, zinc and potassium. Due to the presence of antinutrients in the grain such as tannins and phytates, these micronutrients are less bioavailable. Among grains *Eleusine coracana* popularly known as finger millet was reported to contain high amounts of tannins ranging from 0.04 to 3.47% (Ramachandra *et al*., 1977).

Tannins reduce weight gains and impair feed conversion efficiency. Tannins reduce apparent digestibility of protein and energy (Jansman *et al*., 1993). Tannins are known to have a direct effect on metabolism. Chickens fed high tannin sorghums develop leg abnormalities (Elkins *et al.,* 1978). Tannins impact a bitter taste to the grains making them unpalatable and also interfere with protein digestibility (Harris and Burns , 1970). Barry and Blaney (1987) found that plasma growth hormone levels increased with increased intake of condensed tannins by sheep. Tannins react not only with dietary protein but also with enzymes of the gut wall and proteins in the saliva.

2.3.2.2 Cyanide

Cyanide readily and reversibly binds to a number of proteins and enzymes in the body particularly those with a metallic component. It has a specific affinity for iron in its trivalent (ferric) state and is capable of binding to all enzymes and proteins containing iron, including heamoglobin, myoglobin, catalase and the cytochrome system (Ahmed *et al*., 1996, Uvere *et al.,* 2000). Its most significant interaction is its binding to the ferric iron of the mitochondrial cytochrome oxidase system. Cyanide binds to the cytochrome amino acid complex, thus inhibiting oxidative phosphorylation and paralyzing cellular respiration. This results in anaerobic metabolism, increased lactic acid production, reduced ATP stores and anoxic cell death (Leavesley *et al*., 2007). The

organ systems that are most sensitive to cyanide toxicity are those with the highest oxygen utilization that cannot tolerate hypoxic stress for instance the central nervous system and the myocardium (Muzanila, 1993).

The average fatal dose of cyanide for an adult human is between 50 and 60mg per 100g of dry matter (Panasiuk and Bills, 1984). EFSA (2004) and Salami (1994) quote values of 0.5-3.5mg/kg body weight as lethal dose. The World Health Organization (WHO, 2003) guidelines specify a figure of 0.05mg/kg body weight/day.

The frequency of ingestion and the small body weight of infants may still result in health risk. Any procedure that reduces the cyanide content will thus be highly recommended in the preparation of complementary foods for infants.

2.3.2.3 Phytate

Phytate is a naturally occurring phosphorus compound which significantly influences the functional and nutritional properties of foods. It is the main phosphorus store in mature seeds. Phytate interferes with mineral absorption especially calcium and zinc (Doherty *et al*., 1982).The high quantities of this anti-nutrient in the seed reduce their food value hence causing low utilization unless processed prior to use (Udayasekhara Rao and Deosthale ., 1988; Mukuru, 1992).

Phytate is an effective chelator of positively charged cation. When consumed in feeds it will bind the nutritionally important mineral cations that it encounters in the intestinal tract, such as calcium, iron, and zinc and to proteins as well, forming complexes; the net result is reduced protein and mineral bio-availability.

2. 4 Protein Quality Parameters

2. 4. 1 Feed Efficiency Ratio (FER)

This is the amount of food consumed by the animal divided by the weight of the animal. It is also expressed as weight to gain ratio.

2. 4. 2 Protein Efficiency Ratio (PER)

This is the number of grames of body weight gain of an animal per unit of protein consumed

2. 4. 3 Net Protein Utilization(NPU)

This measures the efficiency of growth by comparing body nitrogen resulting from feeding a test protein with that resulting from feeding a comparable group of animals a protein free diet for the same length of time.

$$\text{NPU} = \frac{(\text{Body N with test protein}) - (\text{Body N with protein free diet}}{\text{Total N intake}} \times 100$$

2. 4. 4 Biological Value (BV)

This is defined as that percentage of nitrogen absorbed from the GIT which available for productive body function. Biological value is determined experimentally by measurement of total nitrogen intake and nitrogen losses in urine and faeces.

$$\text{BV} = \frac{\text{N intake-(fecal N-UrinaryN)}}{\text{N intake-fecal N}} \times 100\%$$

2. 4. 5 True Digestibility(TD)

This makes allowance for the nitrogen in the faeces of non- dietary origin (the so called metabolic nitrogen (F0) which is subtracted from the total feacal nitrogen

$$\frac{N1-(NF1-NF0)}{N1}$$

Where N1= nitrogen intake of the animals

NF1= nitrogen excreted in the faeces of the animals fed with test diet

NF0= nitrogen excreted in the faeces of the animals fed with protein free diet

CHAPTER 3

MATERIALS AND METHODS

3. 1 Materials and Reagents

3.1.1 *Eleusine coracana* Seed

The *Eleusine coracana* seeds were obtained from a local farm in Jama'a local government area of Kaduna State, Nigeria**.** The guinea corn, corn oil, maize offal, limestone, vitamin premix were obtained from the Institute for Agricultural Research (IAR) Ahmadu Bello University, Zaria, Nigeria.

3. 1. 2 Reagents

Petroleum ether, sulphuric acid, hydrochloric acid, boric acid, sodium hydroxide, potassium thiocyanate, ammonium hydroxide, sodium carbonate, potassium iodide, calcium chloride, potassium sulphate, copper sulphate, Orthophosphoric acid, methanol and acetone were purchased from British Drug House (BDH) Ltd., England

3. 2 METHODS

3. 2. 1 Seed Processing

The finger millet seeds (*Eleusine coracana*) were divided into five portions and processed differently according to the method of Eyo (1999). The different processing methods include; boiling, soaking, roasting and fermenting. The finger millet seeds portion that were not processed with the above method were considered as unprocessed seed.

a. The boiling process was done in an aluminum pot using one part of the raw whole seed to 10 parts of clean water on a stove for exactly 30 minutes. The boiled seeds were then sun-dried.

b. Traditional roasting was done at a temperature of 100-110^{o}C by constantly stirring the seeds to prevent charring in a dry aluminum pot until browned. The roasted seeds were exposed to air to hasten cooling.

c. Soaking process was done by covering one part of raw seed with ten parts of water for twelve hours.

d. Fermentation was done by soaking the seed in clean water and covering with a sack for 24 hours. Both the fermented and the soaked seeds were also sun-dried. The different processed finger millet seeds were milled each to obtain homogenous powder and were stored differently in cellophane bags.

3. 2. 2 Preparations of Test Diets

Experimental diet was prepared according to the method of Chapman *et a,.l* (1959) for preparing test diet which includes; corn starch (80%), corn oil (10%), non-nutritive cellulose (5%) mineral mixture (4%) and vitamin mixture (1%). The test feeds were then prepared by incorporating raw or processed finger millet seeds as protein source at 10% level in the feed at the expense of corn starch. The negative control diet was without protein source, while the positive control diet contains casein (10%). The control and test diets were fed to respective animal groups along with water *ad libitum* for 8 weeks (56 days) and the growth performance of the experimental animals were analyzed.

3. 2. 3 Growth Performances of Experimental Rabbits

Forty two male weaner rabbits (about 3 weeks old) were equally divided into seven groups with six animals in each group. The control and test diets were fed to respective animal groups along with water *ad libitum* for 8 weeks and the growth performance of the experimental animals were analyzed.

Body weight gain (BWG), feed efficiency ratio (FER), and protein efficiency ratio (PER) were calculated according to the method of Chapman *et al* (1959). The parameters were determined using the formulae below;

Feed Intake (FI) = [Dry feed consumed (g)/animal]/56 days

$$\text{Body weight gain (BWG)} = \frac{\text{Final body weight (g)–initial body weight (g)}}{\text{Initial body weight (g)}} \times 100$$

Protein efficiency ratio (PER) = Body weight gain (g)/Protein consumed (g)

3. 2. 4 Nitrogen Balance Studies

The nitrogen balance studies were conducted for 14 days with 42 weaner rabbits. The rabbits were randomly separated into seven groups with six animals in each group and housed in wire gauzed cages. The animal groups were fed with control diets, raw and processed finger millet seeds. After 7 days of acclimatization period, the urine and faeces of the experimental animals were collected for seven days.

The nitrogen content of the urine and faeces was estimated by micro-kjeldahl method (AOAC, 2000) and the values of True Digestibility (TD) and Biological Value (BV) were determined by following the method of Chick *et al* (1935) and the Net Protein Utilization, (NPU) was determined by method described by Platt *et al* (1961). The indices were calculated using the formulae below;

$$\text{True Digestibility} = N_I - \frac{(NF_I - NF_O)}{N_1} \times 100$$

$$\text{Biological valve (BV)} = \frac{N_I-(NF_I-NF_0)-(NU_I-NU_O)}{N_I-(NF_1-NF_2)} \times 100$$

$$\text{Net protein utilization (NPU)} = \frac{N_1 - (NF_1-NF_0) - (NV_1-NU_0)}{N_1} \times 100$$

Where,

N_1 = Nitrogen intake of the animals

NF_1 = Nitrogen excreted in the faeces of the animals fed with test diets

NFo = nitrogen excreted in the faeces of the animals fed with protein free diet

NU_1 = Nitrogen excreted in the urine of the animals fed with test diet

NU_0 = Nitrogen excreted in the urine of the animals fed with protein free diet

3. 2. 5 Fluid Intake

The fluid intake was determined by using calibrated feeding bottles, the initial volume was noted and the final volume after 24 hours was determined.

Table 3.1 Feed Formulation Table for Processed and Unprocessed Finger Millet Seed per 100g

Ingredients (g)	**Treatment**						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Corn starch (guinea corn)	8.6	8.6	8.6	8.6	8.6	80	--
Corn oil	10	10	10	10	10	10	10
Non nutritive cellulose (maize offal)	5	5	5	5	5	5	5
Mineral mixture (limestone)	4	4	4	4	4	4	4
Vitamin premix	1	1	1	1	1	1	1
Tamba seed	71.4	71.4	71.4	71.4	71.4	-	-
Casein	-	-	-	-	-	-	71.4

Note: T_1 = Animals fed with raw finger millet seed, T_2 = Animals fed with soaked finger millet seed, T_3 = Animals fed with boiled finger millet seed, T_4 =Animals fed with fermented finger millet seed, T_5 = Animals fed with roasted finger millet seed, T_6=Animals fed with only carbohydrate based diet (negative control), and T_7 = Animals fed with casein diet (positive control).

3.2.6 Carcass Evaluation of Experimental Rabbits

At the end of the experiment, three rabbits per treatment were selected, weighed, slaughtered and eviscerated for carcass evaluation. The rabbits were skinned, the head, tail, skin and legs were cut off and weighed, each animal was cut opened, the alimentary canal, heart, liver, lungs, kidneys and spleen were removed and weighed individually. The skinned carcass were dissected into retail cuts of loin, shoulder and thigh and weighed individually. The weights were expressed as the percentage of the live weight.

3. 2. 7 Determination of Ash Content

The method described by AOAC (2000) was used. A clean crucible was dried in an oven, cooled and weighed (W_1). Exactly 0.5g of the sample was placed in the crucible and the crucible was reweighed (W_2). It was then transferred into a furnace, which was set at 550^0C and left for 8 hours to ensure proper ashing. The crucible containing the ash was then removed cooled and weighed (W_3). Ash content was calculated as follows;

$$\% \text{ Ash} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

3. 2. 8 Determination of Lipid Content

The lipid content was determined as in the method of AOAC (2000). Two round bottom flasks were washed and few anti-bump granules were added to prevent bumping. Petroleum ether of (40-60^OC) boiling point and volume (300ml) were poured into the flask. These were fitted into the Soxhlet extraction units. Extractor thimbles were weighed and 2g of samples were added. The thimbles were fixed into the Soxhlet extraction unit and the cold water circulation was also put on. The heating mantle was switched on and solvent refluxing was adjusted at a steady rate. Extraction was carried out for 8 hours. The thimble was removed and dried to constant weight in an oven at

70^0C and was weighted (W_2). The extractible lipid content of the sample was determined as follows;

$$\% \text{ lipid} = \frac{\text{Weight of lipid extracted}}{\text{Weight of dried sample}} \times 100$$

3. 2. 9 Determination of Crude Protein (Pearson, 1986*)*

Exactly 0.2g of the sample was weighed into 100ml Kjedahl flask and few anti bump granules was added. One gram of catalyst (K_2S0_4 and $CuS0_4$) was added to speed up the reaction. The flask was placed on a Kjedahl rack and heated until a clear solution was obtained. At the end of digestion, the flask was cooled and the sample was quantitatively transferred to a 100ml volumetric flask and made up to the mark with distilled water. After cooling, 10mls of the digest was pipetted into Markham semi micro nitrogen still and 10ml of 40% sodium Hydroxide solution was added. The sample was steam distilled librating ammonia into a 100ml conical flask containing 10ml of 40% Boric acid and 2 drops of methyl red indicator. Distillation is continued until the pink colour of the indicator turns greenish. The control was titrated with 4% boric acid with end point indicated by a change from greenish to pink colour. The volume of the acid for each sampled distillate was noted as well as that of blank. The percentage (%) total nitrogen (N) per sample was calculated as

$$\% \text{ N} = \frac{V_1 - V_0 \times M \times 14 \times 100 \times 100}{0.2 \times 1000 \times 10 \times 1}$$

V_0 = Vol. of HCL required for blank

V_1 = Vol. of the HCL required for 10ml sample solution

M = Molarities of acid (0.1M)

14 = atomic weight of N_2

100 = total volume of digest

100 = % conversion

10 = Volume of distillate

0.2 = amount of sample taken in gram

1000 = to convert to liter

The crude protein was calculated as % crude protein (P) = 6.25 x N Note: Protein contains 16% N. This makes the general conversion factor to be 6.25

3. 2. 10 Determination of Crude Fiber

The method described by AOAC (2000) was used.

Two grams of finely ground sample was put into a round bottom flask, 100ml of 0.25M H_2S0_4 was added and the mixture boiled for 30 minutes. The hot solution was quickly filtered. The insoluble residue was washed with hot water until it is base free it was dried to constant weight in an oven at 100^0C cooled in a desicator and weighted (C_2), the weighed sample was incinerated in a furnace at 550^0C for 2 hours, cooled and reweighed (C_3). The crude fibre was calculated as the loss in weight on ashing.

$$\% \text{ crude fibre} = \frac{C_2 - C_3}{W_1} \times 100$$

Where; W_1 = Weight of the original sample (2g)

3. 2. 11 Determination of Carbohydrate

This was determined from the percentage difference of the other proximate indexes as follows; % carbohydrate = 100 – (% protein + % lipid + % Ash + % crude fibre)

3. 2. 12 Procedures for Analysis of Elements

Mini Pal is a compact energy dispersive X-ray spectrometer designed for the elemental analysis of a wide range of samples. The system is controlled by a PC running the dedicated mini analytical software. The Mini Pal 4 version used is PW 4030 X-ray Spectrometer, which is an energy dispersive microprocessor controlled analytical instrument designed for the detection and measurement of elements in a sample (solids, powders and liquids), from sodium to uranium.

The sample for analysis was weighed and ground in an agate mortar and a binder (PVC dissolved in Toluene press into a pellet). The pellet was loaded in the sample chamber of the spectrometer and voltage (30kV maximum) and a current (1mA maximum) was applied to produce the X-rays to excite the sample for a preset time (10mins in this case). The spectrum from the sample was analyzed to determine the concentration of the elements in the sample.

3. 2. 13 Determination of Saponins

The method described by AOAC (2000) was used. A known weight of dry ground sample was weighed into a thimble transferred into the Soxhlet extraction chamber fitted with a condenser and a round flat bottom flask, some quantity of acetone enough to cause a reflux was poured into the flask. The sample was exhaustively extracted of its lipids and interfering pigments for 3 hours by heating the flask on a hot plate and the solvent distilled off. This is the first extraction. For the second extraction, a pre weighed round bottom flask was fitted into the soxhlet apparatus bearing the sample containing thimble and methanol was poured into the flask. The methanol was enough to cause reflux. The saponin was then exhaustively extracted for 3 hours by heating the flask on

a hot plate after which the solvent was distilled off. The flask was re-weighed. The difference between the final and initial weights of the flask represents the weights of the saponins extracted.

$$\% \text{ saponin} = \frac{\text{Weight of Saponin}}{\text{Weight of sample}} \times 100$$

3. 2. 14 Determinations of Tannins

The method of Allen *et al,*. (1974) was used. Exactly, 0.5g oven dried ground sample was weighed into a 100ml conical flask, 50ml of distilled water was added and allowed to boil for one hour gently on a hot plate. The solution was then filtered while warm in a 50ml volumetric flask. The filter paper was washed, the solution made to mark when cooled.The extract was prepared immediately before use, 0.3 ml aliquot of tannic acid was taken into ranges of 0.5ml volumetric flasks giving a standard range from 0 to 0.3mg, corresponding to 0.05mg, 0.10mg, 0.15mg, 0.20mg, 0.25mg, 0.30 mg respectively. Exactly, 30ml aliquot of the sample was pipetted into a 50ml volumetric flask. To both standards and sample, water was added until half-full. Mixture 2.5ml of folin-Denis reagent (prepared by the addition of 5g sodium tungstate, 1g phosphomolybdic acid and 2.5ml orthophosphoric acid (H_3P0_4) to 35ml of water). It was refluxed for 2 hours, cooled and distilled to 50ml with distilled water and was added to each flask followed by the addition of 10ml 7% w/v sodium carbonate solution and diluted to 50ml mark and mixed. It was allowed to stand in water both at 25^0C for 20 minutes. The absorbance readings were taken at 760nm wavelength using water as reference.

$$\text{Soluble tannins (\%)} = \frac{\text{Conc(mg) x extract volume (ml)}}{\text{10 x aliquot vol (ml) x sample weight (g)}} \times 100$$

3. 2. 15 Determination of Phytate

The method of Reddy 1985 was used

A known weight of each ground sample was soaked into 100ml of 2% HCl for 5 hours and filtered. Filtrate(25ml) was taken into a conical flask, 50ml of 0.3% potassium thiocyanate solution was added. The mixture was titrated with a standard solution of $FeCl_3$ until a brown-yellow colour persisted for 5 minutes.

The concentration of the $FeCl_3$ was 1.40% w/v calculation; mole ratio of Fe to phytate = 1:1.

$$\text{Concentration of phytate phosphorus} = \frac{\text{Titre value} \times 0.064}{1000 \times \text{weight of sample}}$$

3. 2. 16 Determination of Cyanide

Alkaline filtration method (AOAC, 2000) was used.

Exactly l0g of ground sample was soaked in a mixture of 200ml distilled water and 10ml of orthophosphoric acid, the mixture was left for twelve hours to release all bound hydrogen cyanide (HCN). A drop of antifoaming agent (tannic acid) and antibumping agent were added and the solution distilled until 150ml of the distillate was collected. Distillate of about 20ml was taken in a conical flask and diluted with 40ml of distilled water, 8ml of 6 mole/dm^3 ammonium hydroxide and 2ml of 5% potassium iodide solution were added. The mixture was titrated with 0.02moldm^{-3} silver solution using a micro burette until a faint but permanent turbidity was obtained.

3. 2. 17 Determination of Oxalate

Oxalate was determined as described by Oke (1969).

Exactly 1g of the sample is placed in a 250ml volumetric flask. 190ml of distilled water and 10ml of 6MHCl. It was incubated in a water bath at 90^0C for 5 hours. The mixture was centrifuged and filtered into a 250ml volumetric flask and the filterate made up to mark with distilled water. Aliquot(50ml) of the extract was mixed with 25ml 6MHCL of on a hot plate. The brown precipitate formed was filtered off and washed with hot distilled water, the combined solution washings were filtered with concentrated ammonia until the pink yellow colour was formed, the solution was then heated on a hot plate to about 90^0C, the oxalate was precipitated with 10% (w/v) calcium chloride solution. After keeping the mixture overnight, it was filtered and the precipitate washed with distilled water until calcium free as tested with bench sodium hydroxide. The precipitate was then washed with 25% (v/v) sulphuric acid solution and diluted to 125ml with distilled water. It was warmed to 90^0 C and titrated with 0.05N potassium permanganate solution.

$$CaC_20_4 + H_2S0_4 \longrightarrow CaS0_4 + H_2C_20_4$$

$$2Mn0_4 + 5C_20_4^{2} + 16H \longrightarrow 2Mn^{2} + 10C0_2 + 8H_20$$

Calculation:

1m of 0.05 N$KMn0_4$ = 2.2mg oxalate

3. 2. 18 Determination of Moisture Content

Method described by AOAC, (2000) was used in the determination

Principle: This was done based on the difference between the net weight and the weight after drying to a constant (at 100^{o}C) for 24hours.

Procedure: Crucibles were washed and dried to a constant weight in an air oven at 100$_{0}$C. They were later removed and cooled in a desicator and weighed ($W_{1)}$, Ground sample (2g) was placed in the weighted moisture dish (W_2). The crucible containing the sample was kept in an oven at 100$_{o}$C for hours and weighed. It was kept back in oven and reweighed after about 3hours to ensure a constant weight (W_3). And the moisture content was calculated as;

$$\% \text{ Moisture} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

3.3 STATISTICAL ANALYSIS

The data obtained were presented as mean ± standard deviation. The data were then analyzed using One Way Analysis of Variance (ANOVA) followed by Multiple Range Test (Duncan Test).The result were considered statistically significant at $p<0.05$.

CHAPTER 4

RESULTS

4. 1. CHEMICAL COMPOSITION OF DIFFERENT PROCESSED FINGER MILLET SEEDS

4.1.1 Proximate Compositions

Table 4.1 presents the proximate composition of unprocessed and processed finger millet seed. The moisture content of the soaked finger millet seed was significantly different when compared with those finger millet seeds from the other processed methods ($P<0.05$). It was observed that the protein content of the fermented finger millet seed differs significantly when compared with finger millet seeds following the other processed methods ($P<0.05$). While, no significant difference in protein contents was observed within the other processed methods ($P>0.05$).However, protein content of all the processed finger millet seeds differ significantly with the content found in the unprocessed finger millet seeds ($P<0.05$).

Table 4.2 shows; saponins, cyanide and oxalate contents of the fermented finger millet seed were significantly lowered when compared with the values obtained from the other processed methods ($P<0.05$). Tannins and phytate contents were significantly reduced in the boiled finger millet seed as compared with the contents from the other processed methods. Unprocessed finger millet seed showed significant differences in all the anti-nutrient components compared with those from the processed finger millet seeds ($P<0.05$).

Table 4.1 Proximate Composition of Unprocessed and Processed finger millet Seed

Parameters	**Unprocessed Seed(T1)**	**Processed finger millet Seed**			
		Boiled(T3)	**Soaked(T2)**	**Roasted(T5)**	**Fermented(T4)**
Moisture (%)	10.21 ± 0.04^{bc}	14.32 ± 0.07^{b}	15.10 ± 0.11^{a}	8.20 ± 0.04^{bcd}	14.40 ± 0.07^{b}
Lipid (%)	5.28 ± 0.04^{bcde}	10.50 ± 0.04^{a}	9.31 ± 0.04^{b}	6.10 ± 0.04^{bcd}	8.90 ± 0.07^{bc}
Protein (%)	14.00 ± 0.01^{a}	9.60 ± 0.07^{bc}	9.61 ± 0.01^{bc}	7.50 ± 0.04^{bcd}	11.42 ± 0.04^{b}
Fiber (%)	3.51 ± 0.01^{a}	3.20 ± 0.01^{bc}	3.10 ± 0.01^{bcd}	3.41 ± 0.01^{b}	3.01 ± 0.01^{bcd}
Ash (%)	4.22 ± 0.01^{a}	3.41 ± 0.02^{bcd}	3.40 ± 0.01^{bcd}	4.11 ± 0.07^{bc}	3.70 ± 0.01^{bc}
Carbohydrate (%)	62.78 ± 0.01^{b}	59.00 ± 0.01^{bc}	59.48 ± 0.01^{bcd}	70.72 ± 0.01^{a}	58.57 ± 0.12^{bc}

Values with different superscript s in the row are significantly different ($P<0.05$)

Results are expressed as Mean ±SD

Table 4.2. Anti-nutrients Composition of Unprocessed and Processed Finger millet Seed

Parameters	**Unprocessed Seed(T1)**	**Processed Finger millet Seed**			
		Boiled(T3)	**Soaked(T2)**	**Roasted(T5)**	**Fermented(T4)**
Saponins(mg/100g) x 10^{-2}	5.40 ± 0.00^{a}	4.70 ± 0.01^{bc}	4.90 ± 0.00^{b}	4.00 ± 0.00^{bcd}	3.50 ± 0.10^{bcde}
Cyanide (mg/100g) x 10^{-1}	5.55 ± 0.07^{a}	4.25 ± 0.07^{bcd}	5.15 ± 0.07^{b}	4.75 ± 0.07^{bc}	2.75 ± 0.07^{bcde}
Tannins (mg/100g) x 10^{-2}	1.60 ± 0.10^{a}	0.10 ± 0.00^{bcde}	0.90 ± 0.10^{b}	0.20 ± 0.00^{bcd}	0.80 ± 0.10^{bc}
Phytates(mg/100g) x 10^{-2}	3.10 ± 0.01^{a}	2.10 ± 0.04^{bcd}	2.20 ± 0.01^{bc}	2.60 ± 0.10^{b}	2.20 ± 0.01^{bc}
Oxalates(mg/100g) x 10^{-2}	0.68 ± 0.00^{a}	0.15 ± 0.00^{bc}	0.18 ± 0.00^{b}	0.07 ± 0.00^{bcde}	0.09 ± 0.00^{bcd}

Values with different superscripts in the row are significantly different ($P<0.05$).

Results are expressed as Mean ±SD

4.1.2 Mineral Element Concentration of Unprocessed and Processed Finger Millet Seed

The mineral element concentrations of unprocessed and processed finger millet seed are shown in Figure 4.1. Calcium values were significantly high ($p<0.05$) in the unprocessed finger millet while zinc content was significantly low($p<0.05$). Phosphorus was significantly higher in the unprocessed finger millet seed when compared with the values from the processed finger millet seed.

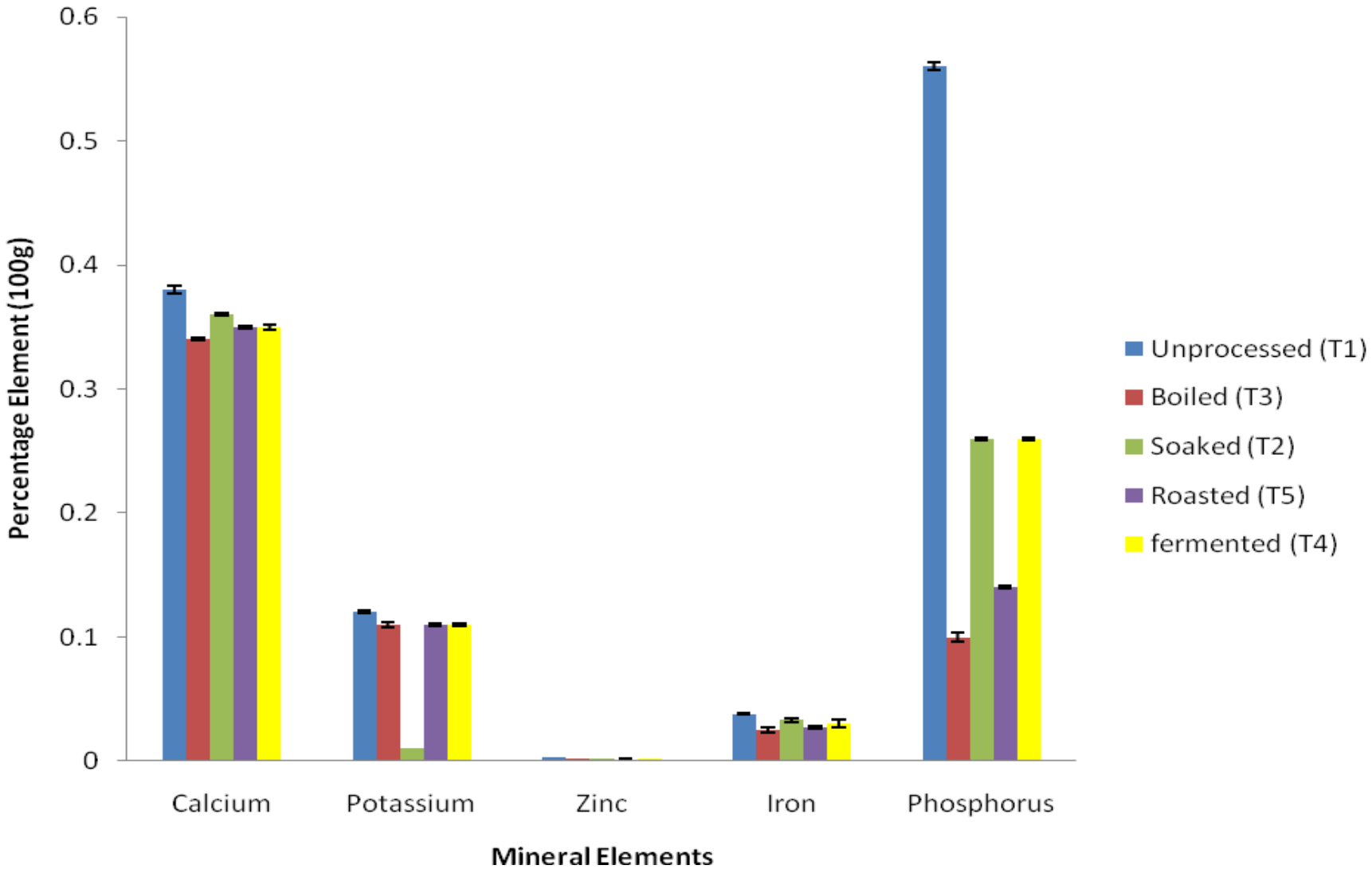


Figure 4.1. Mineral Element Concentration of Unprocessed and Processed Finger Millet Seed

4. 2 Nutritional Quality Indicators of Unprocessed and Processed Finger Millet Seeds

The values for the nutritional quality of unprocessed and processed finger millet seed fed to different group of animals are shown in Tables (4.3a and 4.3b). Protein Efficiency Ratio (PER) of animals fed with the fermented finger millet seed and those fed with the boiled finger millet seed were not significantly different ($p>0.05$)when compared among all the animals' group fed with the processed finger millet seed. However, there was a significant difference in their feed Efficiency Ratio (FER) ($P<0.05$).

The values of nutritional quality like True Digestibility (TD), Biological value (BV) and Net Protein Utilization (NPU) were increased in animals fed diet containing casein as standard protein and differ significantly($p<0.05$) when compared with values found in animals' group fed diet containing different processed finger millet seed ($p<0.05$). However, there was no significant difference in these nutritional indices among the animals' group fed diet containing the different processed finger millet seeds ($P>0.05$). Animals' fed diet containing the unprocessed finger millet seed differ significantly($p<0.05$) in respect to Biological value (BV) and Net Protein Utilization (NPU) when compared with any of the animals in treated groups ($p<0.05$).There was no significant difference in daily feed and water intake among all animals' groups treated ($P>0.05$).

Table 4.3a Nutritional Quality Indicators in Animals' Fed with Unprocessed and Processed Finger millet Seeds

Parameters	Positive control(T7)	Negative control(T6)	Unprocessed seed(T1)	Processed Finger Millet Seeds			
				Boiled(T3)	Soaked(T2)	Roasted(T5)	Fermented(T4)
Protein Efficiency Ratio (PER)	0.19 ± 0.01^{bcd}	8.2 ± 0.10^{bcd}	1.49 ± 0.04^{a}	1.01 ± 0.03^{bc}	1.11 ± 0.03^{b}	1.31 ± 0.72^{b}	0.98 ± 0.01^{bc}
Feed Efficiency Ratio (FER)	4.99 ± 0.46^{a}	3.8 ± 0.03^{bcde}	3.90 ± 0.04^{bc}	4.10 ± 0.18^{bc}	4.36 ± 0.11^{b}	4.15 ± 0.16^{bc}	4.41 ± 0.06^{b}
True Digestibility (TD)	99.26 ± 0.02^{a}	----------	94.41 ± 0.17^{bcd}	95.57 ± 0.93^{bc}	94.52 ± 0.55^{bc}	98.41 ± 0.55^{b}	94.41 ± 0.17^{bcd}
Biological Value (BV)	89.19 ± 0.20^{a}	----------	42.77 ± 2.16^{bc}	52.88 ± 0.96^{b}	50.63 ± 2.53^{b}	54.85 ± 2.23^{b}	42.77 ± 2.16^{bc}
Net Protein Utilization (NPU)	88.59 ± 0.24^{a}	----------	40.39 ± 0.54^{bc}	50.13 ± 0.97^{b}	47.99 ± 2.46^{b}	54.26 ± 2.48^{b}	40.39 ± 0.54^{bc}
No of deaths	-	4	4	3	3	1	4

Values with different superscripts in the row are significantly different ($P<0.05$)

Results are expressed as Mean ±SD. n=6 for each group

Table 4.3b Nutritional Quality Indicators in Animals' Fed with Unprocessed and Processed Finger millet Seeds

Parameters	**Positive control(T7)**	**Negative control(T6)**	**Unprocessed seed(T1)**	**Processed Finger Millet Seeds**			
				Boiled(T3)	**Soaked(T2)**	**Roasted(T5)**	**Fermented(T4)**
Initial Weight (g)	356.7±5.16^{a}	356.7±5.16^{a}	351.7±7.53^{a}	355.0±5.48^{a}	356.7±8.17^{a}	353.3±5.16^{a}	356.7±8.16^{a}
Final Weight (g)	1268.33±19.40^{a}	776±7.67^{b}	985.7±7.07^{bc}	1000.7±1.15^{b}	988.3±2.98^{bc}	1000.6±0.89^{b}	991.7±7.64^{bc}
Daily Feed Intake (g)	46.70±14.19^{a}	39.0±6.56^{a}	36.31±11.60^{a}	40.03±13.52^{a}	36.04±11.65^{a}	40.14±13.46^{a}	35.55±12.12^{a}
Daily Water Consumption (ml)	94.61±0.92^{a}	93.0±1.77^{a}	93.61±1.91^{a}	93.37±2.52^{a}	92.87±1.13^{a}	94.45±2.21^{a}	93.25±1.77^{a}
Body Weight Gain (g)	248.61±6.99^{a}	149.3±0.98^{bc}	177.54±7.52^{b}	180.61±4.43^{b}	179.77±4.19^{b}	183.25±4.26^{b}	180.68±2.62^{b}

Values with different superscripts in the row are significantly different ($P<0.05$)

Results are expressed as Mean ±SD. n=6 for each group

4. 2.1 Change in Body Weight of the Experimental Animals

Change in weekly body weight of animals fed diet containing unprocessed or processed finger millet seed are presented in Figure 4.2. Animals fed diet containing the processed finger millet seed body weight increased slightly during the experimental period while the animals that were fed diet without the finger millet seed, the weight decreased gradually. However, animals fed diet contained the standard protein (Casein) increased in body weight significantly.

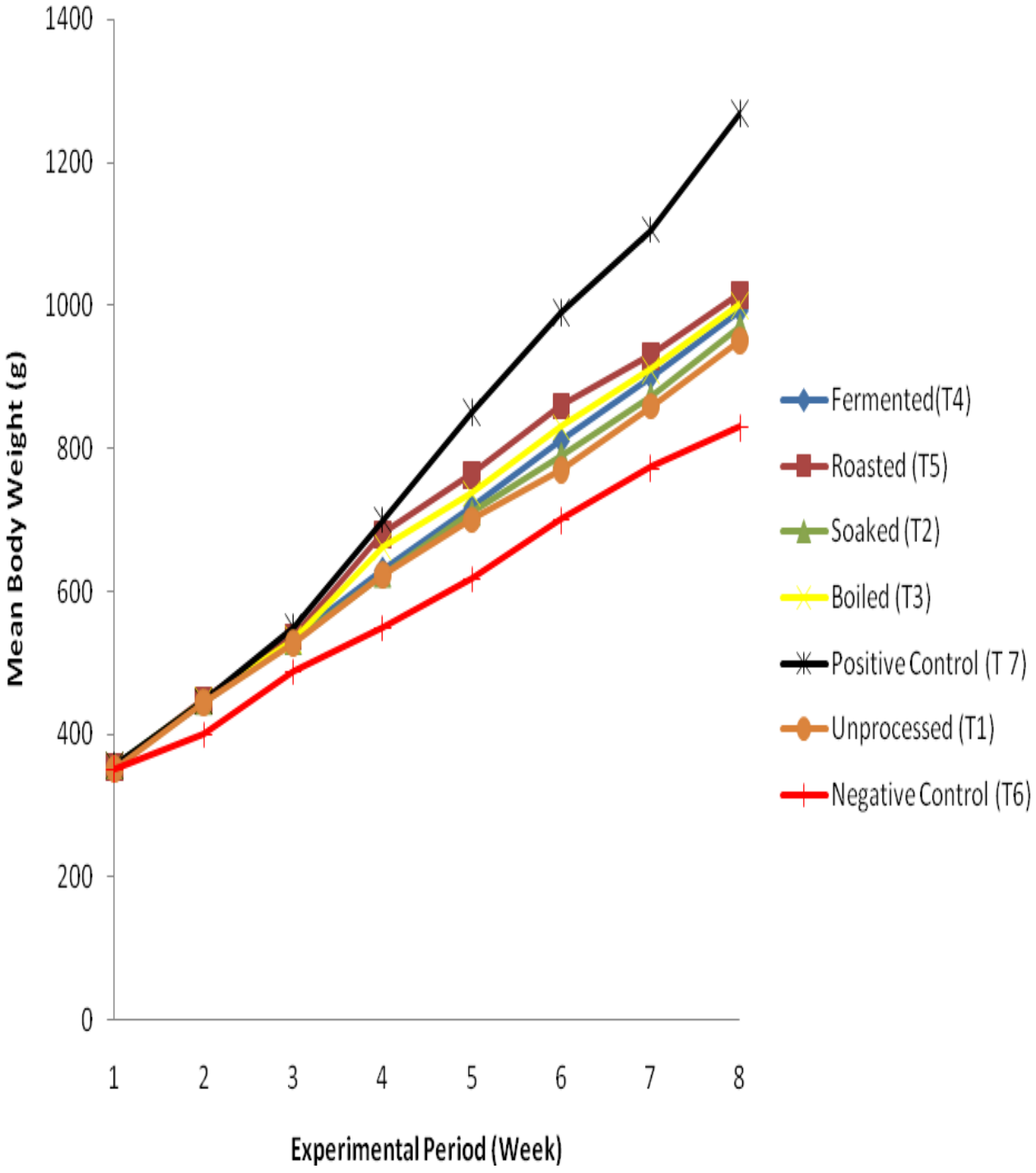


Figure 4.2. Mean Values for Weekly Body Weight (BWG) Gain of Rabbit Fed with Unprocessed and Processed finger millet seeds.

4.3 CARCASS CHARACTERISTICS OF WEANER RABBITS FED WITH UNPROCESSED AND PROCESSED FINGER MILLET SEED

The carcass characteristics of animals fed diet containing unprocessed and processed finger millet seed are presented in Table 4.4. There was no significant difference in live weight among animals' fed diet containing the unprocessed and the different processed finger millet seeds ($p>0.05$), however a significant difference was observed when compared with the live weight of animals in the control groups ($P<0.05$). Kidney weight, Carcass weight and weight of full stomach of animals fed processed finger millet seeds differ significantly ($p<0.05$) while liver, spleen weights and weight of full large intestine did not show any significant difference among the animals fed diet with the processed finger millet seeds ($P>0.05$).

Skin and thigh of animals fed diet containing the processed finger millet seed showed a significant difference within the treated groups which were also significantly different from animals fed diet containing the standard protein (casein and those fed without finger millet seed ($P<0.05$).

Table 4.4a. Carcass Characteristics of Weaner Rabbit Fed Unprocessed and Processed Finger Millet Seed

Parameters	**Negative**	**Positive**	**Unprocessed**	**Processed Finger Millet Seeds**			
	Control (T6)	**Control (T7)**	**Seed (T1)**	**Boiled (T3)**	**Soaked (T2)**	**Roasted (T5)**	**Fermented (T4)**
Live weight (g)	833.00±31.54^{bc}	1248.00±31.54^{a}	976.00±11.40^{b}	1014.00±48.79^{b}	1000.00±28.28^{b}	1053.00±53.81^{b}	976.00±11.40^{b}
Slaughter Wt (g)	811.00±46.43^{bc}	1168.00±19.43^{a}	951.00±16.36^{b}	967.00±9.75^{b}	961.00±7.42^{b}	969.00±9.80^{b}	951.00±16.36^{b}
Carcass Wt (g)	351.00±39.03^{bcd}	578.00±19.03^{a}	431.00±11.47^{bcd}	462.40±10.89^{bc}	453.60±12.30^{bc}	474.20±10.18^{b}	431.00±11.47^{bcd}
Heart (%)	0.20±0.01^{a}	0.22±0.09^{a}	0.21±0.01^{a}	0.21±0.01^{a}	0.21±0.01^{a}	0.22±0.01^{a}	0.21±0.01^{a}
Kidney (%)	0.77±0.07^{bcd}	0.92±0.03^{a}	0.86±0.05^{bc}	0.87±0.05^{bc}	0.86±0.03^{bc}	0.88±0.03^{b}	0.86±0.05^{bc}

Values with different superscripts in the row are significantly different ($P<0.05$)

Results are expressed as Mean ±SD

Table 4.4b.Carcass Characteristics of Weaner Rabbit Fed Unprocessed and Processed Finger Millet Seed

Parameters	Negative Control(T6)	Positive Control(T7)	Unprocessed Seed(T1)	Processed Finger Millet Seeds			
				Boiled(T3)	Soaked(T2)	Roasted(T5)	Fermented(T4)
Liver (%)	1.74±0.62^{bc}	2.86±0.06^{a}	2.40±0.05^{b}	2.41±0.14^{b}	2.39±0.05^{b}	2.41±0.08^{b}	2.40±0.05^{b}
Lungs (%)	0.42±0.14^{bcde}	0.63±0.06^{a}	0.54±0.07^{bcd}	0.55±0.05^{bc}	0.55±0.03^{bc}	0.57±0.04^{b}	0.55±0.06^{bc}
Spleen (%)	0.02±0.02^{bc}	0.05±0.01^{a}	0.03±0.02^{b}	0.04±0.02^{b}	0.04±0.02^{b}	0.04±0.01^{b}	0.03±0.02^{b}
Weight of Full stomach (%)	4.43±0.58^{abcde}	6.51±0.78^{a}	5.06±0.57^{abcd}	5.17±1.25^{abc}	5.22±2.00^{abc}	5.40±2.00^{ab}	5.20±1.00^{abc}
Weight of full Small Intestine (%)	4.17±1.15^{abcd}	6.32±1.11^{a}	5.00±0.00^{abcd}	5.13±0.47^{abc}	5.17±0.58^{abc}	5.27±2.51^{ac}	5.13±1.16^{abc}
Weight of full large Intestine (%)	6.63±1.00^{bc}	9.23±0.56^{a}	8.01±0.58^{b}	8.31±1.25^{b}	8.47±0.57^{b}	8.67±6.11^{b}	8.03±0.58^{b}

Values with different superscript(s) in the row are significantly different ($P<0.05$)

Results are expressed as Mean ±SD

Table 4.4c. Carcass Characteristics of Weaner Rabbit Fed Unprocessed and Processed Finger Millet Seed

Parameters	Negative Control(T6)	Positive Control(T7)	Unprocessed Seed(T1)	Processed Finger Millet Seeds			
				Boiled(T3)	Soaked(T2)	Roasted(T5)	Fermented(T4)
Head (%)	13.30±1.73^{bcd}	22.00±1.12^{a}	19.87±0.58^{bc}	20.00±0.82^{bc}	20.00±0.58^{bc}	20.67±1.16^{b}	20.10±1.00^{bc}
Loin (%)	9.50±7.91^{bcd}	13.23±1.00^{a}	11.92±1.64^{bc}	12.34±0.89^{b}	12.40±1.67^{ab}	12.82±0.84^{ab}	12.40±2.2^{b}
Shoulder (%)	12.72±5^{abcd}	16.39±1.03^{a}	14.20±2.00^{abc}	14.44±0.81^{abc}	14.34±4.88^{abc}	14.72±1.91^{ab}	14.64±5.37^{ab}
Tail (%)	0.36±0.02^{d}	0.51±0.01^{a}	0.44±0.01^{bc}	0.44±0.01^{bc}	0.44±0.01^{bc}	0.45±0.01^{ac}	0.44±0.00^{bc}
Skin (%)	8.67±2.08^{d}	13.02±0.67^{a}	12.16±0.58^{abc}	12.30±0.94^{ab}	12.20±1.00^{abc}	12.33±0.58^{ab}	12.07±0.57^{abcd}
Thigh (%)	12.14 ±2.96^{bcde}	23.50± 2.22^{a}	19.20± 4.47^{bcd}	20.28± 2.28^{bc}	20.34± 3.78^{bc}	21.70 2.74^{ab}	20.60 6.54^{b}

Values with different superscript(s) in the row are significantly different (P<0.05)

Results are expressed as Mean ±SD

CHAPTER 5

5.1 Discussion

The substantial reduction of the ash content in the soaked and boiled samples from 4.22% to 3.40% respectively (Table4.1) might be due to the leaching of both micro and macro nutrients into the soaking medium through the enhanced permeability of the seed coats. Reduction of some anti-nutrients such as tannins, phytate and cyanide following the various processing methods are consistent with the reports of Vijayakumari *et al,*. (1995) and Nithya *et al,*. (2006) that a significant reduction of various anti-nutritional compounds were observed during roasting and boiling of several cereals and legumes such as D*olichos lablab* (*Mucuna monosperma) and Pennisetum glaucum.* In addition, it was observed that reduction in mineral content was due to processing. Reduction of these anti-nutrients will enhance bioavailability of nutrients like calcium, iron, zinc and potassium in the processed finger millet seed.

The growth performance of the experimental animals fed with processed diets was better in animals fed roasted finger millet seed supplement. This could be probably due to the difference between the diets in protein quality and effects of anti-nutritional compounds. Udayasekhara Rao and Belavady (1979a) have shown that the growth performance of rats was better on cooked than on uncooked or raw diets based on different pulse and tuber proteins. Animals fed raw winged bean or its tuber failed to grow and showed a significant loss in body weight, and those fed the tubers even died (Udayasekhara Rao and Belavady, 1979).

Improved growth responses to cooked diets were attributed to the destruction of the anti-nutritional factors present in these foods (Raghunath and Belavady 1979). The Body Weight gained (BWG) value for raw seeds of the present study is in agreement with an earlier report on normal maize (173-179g) (Saharan and Khetarpaul, 1994). Among the different processed seeds, the roasted seeds significantly improved the BWG of rabbits, similar study with pressured cooked seeds of *Canavalis ensiformis (101g)* and *canavalis gladiate (64g)* were found to improve animal's body weight (Bressani *et al.,* 1987).

Soaking of the finger millet seeds did not have a significant ($p>0.05$) effect on the Body Weight gained (BWG) of the animals. It might be due to the presence of some anti-nutritional compounds in the finger millet seeds which are not destroyed completely by soaking and also the daily feed intake is low compared to positive control and other processing methods. The low protein consumption value of boiled, roasted, fermented seeds compared to positive control (casein) could be due to the fact that heat accelerates the millard reaction and makes the protein unavailable (Sagarbieri, 1989). Moreover, usually much of the sulphur containing amino acids such as cysteine and methionine supplied in the diet were used to synthesize pancreatic enzymes (Fernandeze *et al*., 1996).

The protein quality indices such as the True Digestibility (TD), Biological value (BV) and Net protein Utilization (NPU) were found to be improved in animals fed supplement with these processed finger millet seeds (Table 4.3a). Roasting process in this study significantly improved the TD level of finger millet seeds (98.41%) which agrees with the value reported for grains such as *Canavalia ensiformis* (Bressani *et al*., 1987) and Faba bean (71.4%) followed the same processing method (Gupta *et al*., 2005).The consumption

of raw seed proteins was reported to increase endogeneous nitrogen loss through the shedding of intestinal mucosa *(*Sanoja and Bender*, 1983;* Fair weather- Tait *et al., 1983),* an effect that reduces the biological value *of* raw seed proteins.

In addition, presence of various anti-nutritional substances which impede the complete digestion of protein and increases the endogenous faecal excretion of nitrogen (Nestares *et al*., 1966) was also partly responsible for the decrease in protein digestibility value as observed in different processed seeds diet. Improvement in the protein quality after roasting treatment might be attributed to reduction on the levels of various anti-nutrients and to some other factors such as disruption of protein structure and increased accessibility of the seed proteins to enzymatic attack (Nelson, 1991).

Rabbits that received casein as protein source were able to take full advantage of the nitrogen they retained to favor growth, probably as a result of the more balanced supply of amino acids provided by this diet. In rabbits fed with raw finger millet seeds, part of the nitrogen retained may have been rerouted for the synthesis of digestive enzymes such as trypsin and chemotrypsin (Liener, 1994), to offset the effects of the high level of anti-nutrients present in the unprocessed finger millet seeds.

CHAPTER 6

SUMMARY, CONCLUSION AND RECOMMENDATIONS

1.1 SUMMARY

Finger millet seeds were processed differently by boiling, soaking, fermenting and roasting. It was incorporated into the feed of weaner rabbits (3 week old), which were fed for 56 days. Their growth weight were monitored and the nutritional quality of these rabbits were assessed.

Rabbits fed with roasted finger millet exhibited a higher Biological Value (BV), Net Protein Utilization (NPU) and True Digestibility (TD) than other processing methods. This suggests that rabbits were able to utilize the protein and other nutrients completely. The processed and unprocessed finger millet seeds were analyzed for proximate composition, anti-nutrient and mineral element concentrations. Processed finger millet seeds had reduce anti-nutrients and mineral concentrations than unprocessed seeds.

6.2 CONCLUSION

The roasted finger millet seeds proteins exhibit better animal growth performance and protein quality when compared to other processing methods of the study. The results of the present study also indicated that the fermentation treatment is suitable and more effective in reducing various anti-nutritional compounds without affecting the nutritional quality of the finger millet seeds. Hence such economic and potential processing methods could be adapted for the versatile utilization of finger millet seeds as a protein source. Incorporation of such roasted or fermented finger millet seeds in the diets of children or of animals will

clearly reduce the over-dependence on common cereals or legumes for meeting protein requirements in developing countries especially Nigeria.

6.3 RECOMMENDATIONS

Roasting of the finger millet seed before grinding and cooking is recommended to improve the nutritional quality.

Fermentation of the finger millet seed is recommended due to higher reduction of anti-nutritional contents.

Further work is required on other processing methods that can enhance the nutritional value of finger millet.

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APPENDICES

Appendix 1.0 values for weekly body weight gain for the experimental animals

week 1	1	2	3	4	5	6	**Mean**	**SD**
Fermented	350	360	350	360	370	350	**356.6667**	**8.164966**
Roasted	350	350	360	350	360	350	**353.3333**	**5.163978**
Soaked	350	370	360	350	360	350	**356.6667**	**8.164966**
Boiled	360	360	350	350	360	350	**355**	**5.477226**
Control (Casein)	350	360	350	360	360	360	**356.6667**	**5.163978**
Raw Tamba	350	340	360	350	360	350	**351.6667**	**7.527727**
week 2								
Fermented	440	450	440	450	460	430	**445**	**10.48809**
Roasted	440	450	450	450	450	445	**447.5**	**4.1833**
Soaked	440	460	450	440	450	440	**446.6667**	**8.164966**
Boiled	450	450	440	440	450	450	**446.6667**	**5.163978**
Control (Casein)	440	450	440	450	450	450	**446.6667**	**5.163978**
Raw Tamba	440	430	450	430	450	440	**440**	**8.944272**
week 3								
Fermented	530	540	530	530	540		**534**	**5.477226**
Roasted	530	540	540	530	540	540	**536.6667**	**5.163978**
Soaked	530	510	540	530	540	530	**530**	**10.95445**
Boiled	530		530	530	540	530	**532**	**4.472136**
Control (Casein)		540	530	530	530	530	**532**	**4.472136**
Raw Tamba	540		520	520	530	530	**528**	**8.3666**

week 4	1	2	3	4	5	6	**mean**	**SD**
Fermented	620	630		620	630		**625**	**5.77350**
Roasted	620	630	620	630	630	630	**626.666**	**5.16397**
Soaked	620		630	620	630	620	**624**	**5.477226**
Boiled	620			620	630	620	**622.5**	**5**
Control (Casein)			620	610	600	610	**610**	**8.16496**
Raw Tamba	630			620	620	620	**622.5**	**5**

week 5							**Mean**	**SD**
Fermented	710	720			710		**713.333**	**5.77350**
Roasted	710	710	720	720	720	720	**716.666**	**5.16397**
Soaked				710	700	720	**710**	**10**
Boiled	710				710	700	**706.666**	**5.77350**
Control (Casein)					700	710	**705**	**7.071068**
Raw Tamba	710			710	710		**710**	**0**

week 6								
Fermented	800	810			800		**803.333**	**5.77350**
Roasted	800	800		810	800	810	**804**	**5.477226**
Soaked				800	800	800	**800**	**0**
Boiled	800				800	800	**800**	**0**
Control (Casein)					790	800	**795**	**7.07106**
Raw Tamba				800	790		**795**	**7.07106**

week 7	1	2	3	4	5	6	**mean**	**SD**
Fermented	890	900	900				**896.6667**	**5.773503**
Roasted	890	890	900	890	910		**896**	**8.944272**
Soaked	890	900	890				**893.3333**	**5.773503**
Boiled	890	890	900				**893.3333**	**5.773503**
Control (Casein)	1000	1020	1100	1260	1100	1150	**1105**	**94.18068**
Raw Tamba	880	890					**885**	**7.071068**

week 8								
Fermented	985	1000	990				**991.6667**	**7.637626**
Roasted	1000	1001		1000	1002	1000	**1000.6**	**0.894427**
Soaked				985	990	990	**988.3333**	**2.886751**
Boiled	1002				1000	1000	**1000.667**	**1.154701**
Control (Casein)	1250	1270	1280	1300	1260	1250	**1268.333**	**19.4079**
Raw Tamba				990	980		**985**	**7.071068**

Appendix 2.0. Values for anti-nutrient contents in the processed and the unprocessed finger millet seed

	Saponins (%)	Cyanide mg/100g	Tannin mg/100g	Phytate (%)	oxalate (%)
Fermented					
	0.035	0.28	0.008	2.172	0.089
	0.034	0.27	0.007	2.2	0.09
Mean	**0.0345**	**0.275**	**0.275**	**0.275**	**0.275**
SD	**0.00071**	**0.00707**	**0.00707**	**0.00707**	**0.00707**
Soaked	0.049	0.52	0.009	2.175	0.179
	0.049	0.51	0.009	2.176	0.8
Mean	**0.049**	**0.515**	**0.515**	**0.515**	**0.515**
SD	**0**	**0.00707**	**0.00707**	**0.00707**	**0.00707**
Raw	0.054	0.56	0.116	3.112	0.68
	0.054	0.55	0.115	3.11	0.684
Mean	**0.054**	**0.555**	**0.555**	**0.555**	**0.555**
SD	**0**	**0.00707**	**0.00707**	**0.00707**	**0.00707**
Roasted	0.04	0.48	0.002	2.62	0.073
	0.04	0.47	0.003	2.6	0.074
Mean	**0.04**	**0.475**	**0.475**	**0.475**	**0.475**
SD	**0**	**0.00707**	**0.00707**	**0.00707**	**0.00707**
Boiled	0.046	0.43	0.001	2.08	0.146
	0.047	0.42	0.001	2.05	0.146
Mean	**0.0465**	**0.425**	**0.425**	**0.425**	**0.425**
SD	**0.00071**	**0.00707**	**0.00707**	**0.00707**	**0.00707**

Appendix 3.0 Values for weekly Feed and water intake per animal in the experimental group

	Weekly feed intake (g)									
	1	2	3	4	5	6	7	8	**Mean**	**SD**
Fermented	210	224	252	273	294	329	343	350	**35.54688**	**12.12064**
Roasted	231	266	287	322	336	350	378	399	**40.14063**	**13.46731**
Soaked	227.5	245	259	280	294	322	336	343	**36.03906**	**11.65127**
Boiled	224	259	280	336	357	371	385	350	**40.03125**	**13.52698**
Control (Casein)	329	336	350	364	385	399	406	420	**46.70313**	**14.18574**
Raw Tamba	231	252	266	280	301	315	329	350	**36.3125**	**11.6003**
	Weekly water Intake (ml)									
	1	2	3	4	5	6	7	8	**mean**	**SD**
Fermented	91	91	92.5	94	93	93.5	96	95	**93.25**	**1.772811**
Roasted	91	93	92	95	95	96.1	97	96.5	**94.45**	**2.205189**
Soaked	91	92	93	92	93	94	94	94	**92.875**	**1.125992**
Boiled	90	91	92	92.5	93	95.5	96	97	**93.375**	**2.517794**
Control (Casein)	93	93.5	94.5	95	94.8	95.5	95	95.6	**94.6125**	**0.921858**
Raw Tamba	90.8	91.3	92.7	93.6	94	95	95.5	96	**93.6125**	**1.905959**

Appendix 4.0 Values for Proximate analysis for the processed and unprocessed finger millet seeds

	Moisture	Lipid	Protien	Fiber	Ash	Carbohydrate
Fermented						
	14.3	8.8	11.45	3.05	3.66	58.75
	14.4	8.9	11.4	3.06	3.67	58.58
Mean	**14.35**	**8.85**	**11.425**	**3.055**	**3.665**	**58.665**
SD	**0.070711**	**0.070711**	**0.035355**	**0.007071**	**0.007071**	**0.120208**
Soaked	50.05	9.25	9.61	3.11	3.41	40.66
	50.2	9.3	9.63	3.1	3.42	40.65
Mean	**50.125**	**9.275**	**9.62**	**3.105**	**3.415**	**40.655**
SD	**0.106066**	**0.035355**	**0.014142**	**0.007071**	**0.007071**	**0.007071**
Raw	10.15	5.25	14.01	3.45	4.22	60.83
	10.2	5.3	14	3.46	4.2	60.84
Mean	**10.175**	**5.275**	**14.005**	**3.455**	**4.21**	**60.835**
SD	**0.035355**	**0.035355**	**0.007071**	**0.007071**	**0.014142**	**0.007071**
Roasted	8.15	6.05	7.45	3.41	4.16	70.71
	8.2	6.1	7.5	3.42	4.06	70.72
Mean	**8.175**	**6.075**	**7.475**	**3.415**	**4.11**	**70.715**
SD	**0.035355**	**0.035355**	**0.035355**	**0.007071**	**0.070711**	**0.007071**
Boiled	14.2	10.45	9.5	3.14	3.43	59.01
	14.3	10.5	9.6	3.16	3.42	59.02
Mean	**14.25**	**10.475**	**9.55**	**3.15**	**3.425**	**59.015**
SD	**0.070711**	**0.035355**	**0.070711**	**0.014142**	**0.007071**	**0.007071**

Appendix 5.0. Values for Protein Efficiency Ratio (PER) for the experimental animals' fed diet supplemented with processed and unprocessed finger millet seeds

							Mean	**SD**
Fermented	0.981756	0.962001			0.989487		**0.977748**	**0.014175**
Roasted				1.326531	1.27381	1.326531	**1.308957**	**0.717268**
Soaked				1.117171	1.077586	1.125968	**1.106908**	**0.025772**
Boiled	0.995164				0.992063	1.036352	**1.00786**	**0.024724**
Positive control	0.187422	0.18424	0.193669	0.190314	0.182216	0.180191	**0.186342**	**0.005097**
Negative control				1.518747	1.464475		**1.491611**	**0.038376**
No finger millet seed	8.20014	8.220021		8.2301			**8.21675**	**0.01525**

Appendix 6.0. Values for Feed Efficiency Ratio (FER) for the experimental animals' fed diet supplemented with processed and unprocessed Finger millet seeds

							Mean	**SD**
Fermented	4.425087	4.336043	4.45993				**4.40702**	**0.063889**
Roasted				4.046063	4.062263	4.329004	**4.145777**	**0.158886**
Soaked				4.403606	4.247573	4.43828	**4.363153**	**0.101586**
Boiled	3.893741				4.153686	4.240052	**4.095826**	**0.18026**
Positive Control	5.471125	5.266204	5.314286	5.021368	4.545455	4.337232	**4.992611**	**0.455544**
Negative control				3.932412	3.870162		**3.901287**	**0.044017**
No finger millet seed	3.8100	3.7602	3.7921				**3.787433**	**0.025226**

Appendix 7.0. Values for Biological Value (BV) for the experimental animals' fed diet supplemented with processed and unprocessed Finger millet seeds

						Mean	SD
Fermented	53.56125	50.43732		53.59116		52.52991	1.8123
Roasted			60.73953	57.58722	46.20939	54.84538	2.229025
Soaked			52.42165	48.84488	51.42857	50.63327	2.529157
Boiled	53.56125			52.19941	51.05105	52.88033	0.962966
Positive Control			88.96052	89.32902	89.28571	**89.19175**	**0.201423**
Negative control			41.24514	44.29967		**42.77241**	**2.159885**

Appendix 8.0. Values for Net Protein Utilization (NPU) for the experimental animals' fed diet supplemented with processed and unprocessed Finger millet seeds

						Mean	**SD**
Fermented	50.81081	48.05556		51.05263		**49.973**	**1.664951**
Roasted			60.29231	56.77407	45.71429	**54.26022**	**2.487767**
Soaked			49.72973	46.25	49.09091	**47.98986**	**2.46054**
Boiled	50.81081			49.44444	48.57143	**50.12763**	**0.966167**
Control (Casein)			88.32	88.75502	88.70968	**88.5949**	**0.239147**
Raw Tamba			40.76923	40		**40.38462**	**0.543928**