TITLE PAGE

POTENTIAL OF COCOYAM, CASSAVA, LOCUST BEAN AND TAMARIND AS CARBOHYDRATE AND PROTEIN SOURCES IN ANIMAL FEED

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF:

DOCTOR OF PHILOSOPHY

DEPARTMENT OF BIOLOGICAL SCIENCES

FACULTY OF SCIENCE;

AHMADU BELLO UNIVERSITY

ZARIA - NIGERIA

July, 1986

DECLARATION

I declare that this Thesis is my own work and has never been submitted elsewhere in any form for any degree. All information cited from published or unpublished data has been gratefully acknowledged in the text.

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THESIS APPROVAL

This thesis entitled: 'POTENTIAL OF COCOYAM, CASSAVA, LOCUST BEAN AND TAMARIND AS CARBOHYDRATE AND PROTEIN SOURCES IN ANIMAL FEED' by REGINA ALADI EGA (MRS) (NEE: IJACHI) meets the regulations governing the award of the degree of DOCTOR OF PHILOSOPY of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENTS

All praise and all thanksgiving be to God, the Omnipotent and Omniscient, the fountain and source of all knowledge, the Alpha and Omega! Amen! Alleluia!

I wish to sincerely acknowledge with gratitude the invaluable advice, guidiance and criticism throughout the course of this research and thesis preparation of Drs S. Mu'Azu and M. M. Kapu, both of the Department of Biological Sciences, and Professor J. M. Olomu, formerly of the National Animal Production Research Institute, all of Ahmadu Bello University, Zaria. Their tremendous effort and supervision have made this work a reality.

I am also greatly indebted to Drs. G. A. Pitt and H. O. James of the Department of Biochemistry, University of Liverpool, for kindly taking care of all my needs during the period of my research attachment in England.

I express deep appreciation to the technical staff of the Departments of Biological Sciences, Biochemistry, Soil Science, Centre for Educational Technology, National Animal Production Research Institute and the School of Basic Studies, for providing me with the necessary technical assistance and advice. Since the lack of space will not enable me name them all, I shall enumerate only a few names such as; Messrs S. A. Bello, J. Akaa, L. Lawal,

A. Aboh, C. Atayi, C. A. Umoru, J. Oche and Mr and Mrs E. Achegbulu. For experimental design and statistical analysis, I am grateful to Drs L. A. Shirley of the Department of Mathematics Education, B. A. Oyejola of the Institute for Agricultural Research and Mr S. Olorunju of the National Animal Production Research Institute, all of Ahmadu Bello University, Zaria.

I am grateful to my parents who dared to send me, a girl, to school and to my relations, especially, Juliana O. Ijachi, Late WO II Enokela, Major and Mrs W. A. and Capt. L. E. Ugbo, Mama Omneje and Late Ogwa Ugbo, Mr B. Adeka, Late Iteji and Alugboju Ochoche, Mr Ochoche Otokolo, Oche Ogo and Ene Adeka, who helped me in their various capacities.

I also thank my husband, Dr L. A. Ega and Professor A. A. Olatunde for giving me the initial push and encouragement to register for this course. I am greatly indebted to numerous friends and relatives, some of which include: Drs A. Oladimeji, C. O. Ikediobi, Late Mrs O. Adebisi, Miss T. Akenova, Mrs F. Folarammi, Mrs. A. Shirley and my brother-In-Law, Dr James Ega. The latter cheerfully made himself available at the time the family most needed him. I must also thank my children Oyifioda, Ojonye, Oiwodu, Olije, Ijachi, Inalegwu and my husband Dr L. A. Ega, for their understanding, patience and endurance throughout the course of this study.

Acknowledgement is gratefully extended to the Catholic Mission, particularly, the Holy Rosary Sisters, and with pleasure, to Srs. Catherina, Monica and Edith for giving me relevant Foundation Education.

Similarly, I would like to thank Ahmadu Bello University, Zaria for giving me the opportunity and sponsorship. I would like to specifically thank my department, the School of Basic Studies and the Principal, Dr M. S. Abdulrahman for his understanding, ready cooperation and assistance throughout the course of this study. I am also grateful to Dr D. Adegboye, the Head of Department of Biological Sciences, Ahmadu Bello University, Zaria and its other staff members who worked hard to see me through this work. Gratitude is also due to Benue State Scholarship Board for partially sponsoring this course during the period of my study fellowship.

Finally, I would like to thank Mr Edwin A. Onuh for his patient understanding and for never being tired of typing and retyping.

To you all I am humbly grateful.

Regina Aladi Ega (Mrs)
(Nee: Ijachi)

DEDICATION

THIS THESIS IS DEDICATED IN EVERLASTING MEMORY OF MY DEAR PARENTS, IJACHI AND OIJIGWO UGBO; AND WITH ALL MY LOVE TO MY CHILDREN, OYIFIODA, OJONYE, OIWODU, OLIJE, IJACHI AND INALEGWU AND WITH DEEP FEELINGS TO THE CATHOLIC MISSION, ESPECIALLY, THE HOLY ROSARY SISTERS.

ABSTRACT

The proximate, mineral and amino acid contents of two carbohydrate and two protein foodstuffs, obtained from Zaria markets of Kaduna State of Nigeria, were determined using standard methods of analysis. The foodstuffs analysed include; the unpeeled, peeled and the peels of sweet cassava root tubers (Manihot palmata Muell) and the corms of taro cocoyam (Colocasis esculenta Schott-Holl), whole seeds, seed nuts (Kernels) and the seed testa of the African locust bean (Parkia clappertoniana Keay) and the tamarind (Tamarindus indica Linn - Holl.) These foodstuffs were then biologically evaluated by using weanling albino rats in feeding trial experiments.

Results of the chemical analysis revealed that the traditional way of peeling the cassava and cocoyam with the intention to remove an appreciable amount of anti-nutritional factors and poisonous or toxic principles also reduced the high fibre content. The peeled portions of both cassava and cocoyam were highest in organic matter, nitrogen - free - extract, total carbohydrates and calories followed by the unpeeled while the peels had the lowest values. Cocoyam contained more protein, ash and minerals than cassava. Cassava had higher amounts of crude lipid, the amino acid arginine and calories than the cocoyam. Both tubers contained more arginine than Parkia and Tamarindus.

Dehusking or Shelling the legume seeds and then cooking and fermentation tended to decrease the crude fibre but increase the crude protein, some amino acids, mineral elements and energy of the seeds. Both Parkia and Tamarindus seeds were relatively high in crude protein, lipid and calories. Parkia tended to contain more of these nutrients including ash and amino acids than Tamarindus.

Results of the biological evaluation experiements showed that generally, the cassava and cocoyam - based diets gave poorer weight gains, feed conversion ratio (FCR), protein efficiency ratio (PER), biological value (BV) and net protein utilisation (NPU) than the corn-based diets. Although rats on the cassava - based diets performed slightly better than those on the cocoyam - based diets, the difference was not significant. Also, performance of rats on the casein diets were found to be superior to those on both Parkia and Tamarindus diets, irrespective of the type of carbohydrate source used although, Parkia seemed to cause better weight gains, FCR, PER, BV and NPU than Tamarindus.

Furthermore, methionine supplementation seemed to improve protein intake, weight gains, FCR, PER, BV and NPU of the rats on the experimental diets. This fact seemed to show that methionine addition might have improved the essential amino acid balance of both casein and seed proteins. Also casein-methionine supplemented diets performed better than both Parkia and Tamarindus supplemented

diets. This tended to support the general belief that like most animal proteins, casein has better amino acid profile than Parkia and Tamarindus as well as confirm that casein is also deficient in methionine. Furthermore, the supplemented Parkia diets gave better performance than the supplemented Tamarindus diets. The explanation might be due to the higher contents of protein and essential amino acids in Parkia than in Tamarindus.

This study reveals that since both cassava and cocoyam were found to be deficient in protein and essential amino acids, including methionine, and Parkia and Tamarindus, though high in protein, were also deficient in some essential amino acids such as methionine, the overall deficiency, coupled with other nutrient factors such as, the presence of hydrocyanic acid in cassava, oxalic acid and sapotoxins in cocoyam, might have been responsible for the poor values obtained for the measured biological indices of experimental animals.

Contributions to knowledge accomplished by the findings of this study were highlighted by both the chemical and biological evaluations of the nutritional values of Tamarindus seeds. Another important aspect was the simultaneous and comparative evaluation of the amino acid compositions of cassava, cocoyam, Parkia and Tamarindus. Also, the Feeding trial experiments indicated that methionine supplementation of Parkia and Tamarindus proteins may be beneficial to animals on cassava and cocoyam diets.

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ABBREVIATIONS, GLOSSARIES AND SYMBOLS AS OCCURED IN THE TEXT

AD	=	Apparent Digestibility
BV	=	Biological value
CAP	=	Common Agricultural Policy of the European Economic Community (EEC)
CM	=	Centimeter(s)
CS/PS	=	Chemical/Protein Score
d.f.	=	degrees of freedom
EAAI	=	Essential Amino Acid Index
E:N	=	Essential to Non-essential amino acid ratio
E:T	=	Essential amino acid per grammes Total Nitrogen ratio
et. al.	=	and others
FAO	=	Food and Agricultural Organisation of United Nations
FCR	=	Feed Conversion Ratio
HCN	=	Hydrocyanic Acid (also called prussic acid)
i.e.	=	That is
IDRC	=	International Development Research Centre, Canada
INCAP	=	Institute for Nutrition of Central America and Panama
i.u.	=	International Units
Kcal(s)	=	Kilocalorie(s)
Kg	=	Kilogramme(s)
M	=	Meter(s)
mg	=	Milligramme(s)
ml(s)	=	Millilitre(s)
NAS/NRC	=	National Academy of Sciences, National Research Council

NFE	=	Nitrogen - Free - extract
NPU	=	Net Protein Utilisation
PAG	=	Protein Advisory Group
P	=	Probability
PER	=	Protein Efficiency Ratio
pH	=	indicates degree of acidity or alkalinity
ppm	=	parts per million
^{o}C	=	degrees centigrade
%	=	percent
<	=	less than

CHAPTER ONE

1. INTRODUCTION AND LITERATURE REVIEW

1.1. Statement of the Research Problem

Today, many of the problems of nutrition are being studied with small animals such as the rat. However, studies with the rat can only serve as pilot experiments, by which much preliminary information can be obtained more quickly at less cost than with large animals. Such experiments with rats can determine what ideas are of sufficient promise to justify the expense involved in giving them a final test with large animals (Maynard et. al., 1979). Nigeria, like other countries, conduct research in almost all fields of human endeavour and uses laboratory rats in vast numbers. Nutrition is one of these areas of research. This is more so because inadequate and unbalanced nutrition is one of the main obstacles to livestock production and has been a problem in human nutrition.

Scientific and economical feeding requires the provision of a balanced ration, by which the animal is supplied daily with the correct amounts of the various feed constituents necessary to maintain bodily growth and vigour (Wood and Woodman, 1939). The compounding of a balanced ration or diet necessitates, therefore, a knowledge of the composition of the various foodstuffs employed and the principles on which the calculation is based (Georgi, 1934).

Among nutritional requirements, the need for energy or fuel ranks second to water (Pushpamma, 1968). An animal's fuel consists

largely of carbohydrates and fats. Cereals, such as corn (Maize), Sorghum (guinea corn), wheat, rice, millet, barley, oats and rye are amongst the highest yielding crops and are second only to root crops in their energy yields. In addition to calories, cereal grains also contain some protein, minerals and vitamins. The current prohibitive prices of cereals and the competition between man and animals emphasize the need to find cheaper alternative energy sources.

Cassava is widely recognised as an acceptable and a cheap alternative energy source. Cassava enjoys some advantages over grains. These include high dry matter and energy yield per hectare, low production costs and relatively low susceptibility to insect and pest attack (Obioha 1978). Other tubers and root crops such as yams, potatoes and cocoyam are highly consumed by humans. These tubers and root crops are even more economical in terms of energy yield than cereals. For instance, cassava provides 13 times more energy per hectare than maize or guinea corn (Oyenuga, 1968). And yet they have not been biologically evaluated nor nutritionally exploited as much as cereals. It is therefore pertinent to evaluate these foodstuffs and use them as alternative sources of carbohydrates and energy.

In addition to calories, the animal also requires protein for proper nutrition. Protein malnutrition is most critical in that part of the world population subsisting mainly on cassava

and root crops, but is also widespread among the cereal-consuming populations (Pushpamma, 1968). Accordingly, animal feeds and human foods prepared from cereals have always been enriched with animal proteins such as milk, eggs, meat, fish and shell-fish. Plant proteins from legumes such as winged beans, soybeans, cowpeas, chicken peas, groundnuts, beniseed, cashew nut and coconut (Fetuga, 1974) which are protein rich have been recently employed. These are still expensive and insufficient. There is thus the need to evaluate other sources of protein.

Kapu (1980) determined the protein and mineral values of seeds and fruits of some Nigerian Savanna Trees; Eka (1980) reported on the nutrient status of fermented African Locust Bean seeds; Obode (1982) reported on the Chemical analysis of Parkia clappertoniana, Adansonia digitata and Tamarindus indica seeds obtained from Zaria markets while Okeoma (1984), compared the chemical composition of fermented African locust bean seeds with synthetic flavour enhancers. Okpala (1985), carried out studies on seasonal changes of nutrient contents of Parkia clappertoniana. These workers reported varying protein values (10.9-43 percent) for both Parkia clappertoniana and Tamarindus indica seeds thus indicating their potential nutritive values. It was considered necessary to evaluate these last two seeds biologically.

The present research was designed to determine the replacement value of starch from cassava root tubers and cocoyam corms for corn

starch. These starches were evaluated together with fermented African locust bean and the tamarind seeds in order to determine the suitability of these plant protein sources as animal feeds.

1.2 Review of the Literature

1.2.1. Carbohydrates as energy sources

1.2.1.1. Cereal grains

The World's principal source of carbohydrates is cereal grains followed by roots and tubers and then grain legumes or pulses. It has been asserted that man and animals would find it hard to exist without cereal grains (Coffman, 1966). Cereal grains contribute more than any other single group of feed staples to both calories and protein in the human diet. In its major document on World and Agriculture Development Plans published in 1966, the Food and Agricultural Organisation (FAO) stated that cereals, particularly wheat, rice, maize, sorghum, millet and barley provided more than 50 percent of calories and protein for the people of Africa, South of the Sahara, more than 60 percent of calories and protein for the people of Asia and more than 65 percent calories and protein for the people of the Near East. In Central America, maize provided 57 percent of the daily intake of calories and 45 percent of the daily protein intake for the adult population (PAG, 1970).

Selby (1977) reported that the major cereal-based products used in the European food industry are derived from maize, wheat and to a lesser extent, barley. Rice is increasing in importance in the USA and the Far East. Maize products have dominated the processed commodity for many years and the crop produces starch, oil and protein, the latter being used in animal feeds. Economically, developed countries such as the USA produce more cereals than developing countries like Nigeria. In addition, most of the cereals produced in developed countries is consumed by animals while humans directly consume the cereals in developing countries (PAG, 1970). For example, according to 1970 USA estimates (Shroder and Heiman, 1970), out of the 4 billion bushels of corn (maize) produced, 10 percent of this was processed commercially. The rest was mostly used as animal feed. Even 25 - 35 percent of the commercially processed corn was used as animal feed. And this amount accounted for 3 million tons of feed products, corn providing 50 percent of the ingredients of the animal feed industry. After processing for corn starch and corn oil, the remains usually go into animal feed production. For instance, the gluten, which is high in protein is used in poultry feeds and ruminant rations. The physical and chemical alterations of the fibrous portion of corn makes it more digestible, while pelleting gluten feed significantly improves nitrogen utilisation by rats and pigs.

The main contribution of cereals and pulses to the food economy of Nigeria consists in their nutritional value, especially their richness in protein. The protein content of these grain crops varies from 22.7 percent for cowpeas and 15.03 percent for guinea corn to 12.51 percent for rice and 10.67 percent for maize (Oyenuga, 1968). Guinea corn, millet, maize, cowpeas and rice accounted for 76.9 percent cultivated land in 1970/71 with guinea corn in the leading position (Agboola, 1979). Yet, the production is still too inadequate to meet demands and Nigeria has to import substantial amounts of cereals and animal protein (IDRC, 1975). For instance, in Northern Nigeria, 64 percent of the total calories are derived from cereals, 17 percent from yams and cassava, 9 percent from pulses and nuts and 4 percent from fats and oils (FAO, 1965). Because of this unhealthy dependency on cereals, there is an urgent need to find alternative sources of energy and protein. Even animal feed compounders in the European Economic Community who still depend heavily on cereals have begun to use cassava and tallow as cheaper substitutes (Turret Press, 1976).

1.2.1.2. Tuber and root crops

The first serious scientific approach to substituting cereals with tuber and root crops in compounding animal feeds began as far back as the early years of the Second World War when cassava was used in commercial pig production (Leite, 1939). Later, Oyenuga

et. al. (1955, 1957 and 1968) working in Nigeria, produced satisfactory growth in pigs using cassava diets. Jeffers and Hynes (1967), using rats, also found that cassava and other root crops produced satisfactory growth and food efficiency at levels up to 20 percent. Maust et. al. (1969) successfully replaced maize with 36 percent cassava meal. Also Cerpacio et. al. (1974) using sweet potatoes, cassava, yams and cocoyam in broiler rations, found that potato and cassava could probably replace yellow maize. Similarly, Tewe et. al. (1976 and 1979) analysed and determined the food preferences of the African giant rat using some common tropical foodstuffs which included sweet potatoes, yams, cassava and cocoyam and found that they were the most relished by the rats, with sweet potatoes topping the list.

In the Western World, the most widely cultivated of the tuber and root crops is the Irish potato (Solanum tuberosum). Next comes a number of tuber-yielding plants mostly tropical in origin and cultivated in the tropical and subtropical parts of the world. For example, in India, the more important cultivated tubers, next to potatoes, are tapioca (cassava), sweet potato, taro cocoyam and various types of yams (Abraham, 1970).

It has been estimated that the current production of tropical root crops is of the order of 1.4×10^8 tons/annum. This represents the staple food of around 4×10^8 people. Half of this is derived from cassava, and about 12 percent from yams. These estimates

indicate that yams already make a sizeable contribution to the feeding of the tropical world. The main area of production is West Africa, but the Caribean, parts of Southeast Asia and the Pacific are also major yam producers (Coursey et. al., 1970).

The main root crops of Nigeria are yams, cassava and cocoyam. Sweet potato and Irish potato are grown only in a few restricted areas and as the volume of production is limited, they are considered as minor crops. Root crops occupy a significant position in Agricultural production generally and in the country's food economy in particular. The value of root crops produced in 1957 was 54.6 percent of all crops for domestic use, and 41.8 percent of all crops. Total root crop production was estimated to be worth ₦394.1 million in that year. However, in terms of land use, the amount of land devoted to the cultivation of the three leading root crops is not as significant. For in 1970/71, the 1.8 million hectares on which root crops were grown represented only 10.1 percent of land devoted to the more important food crops, and 8.8 percent of the major arable crops. This implies that these root crops, especially yams and cassava, have high relative value per unit of land used in their cultivation when compared with other crops, especially the cereals.

Root crops are cultivated more in the eastern states than in the western states. For instance, root crops form 85.9 percent of all crops consumed in the eastern parts while they form 78.6

percent of those consumed in the west. On the whole, root crops are the main source of carbohydrates in the southern parts of Nigeria (east and west) while cereals are the leading food crops in the northern parts. In the north, a variety of root crops are grown only as supplements and these include yams, cocoyams, cassava, Irish potatoes and sweet potatoes (Agboola, 1979), hence these crops are being under-utilised while there is room to expand their production and encourage their utilization.

1.2.1.3. Cassava (Manihot palmata Muell)

Cassava is native to Brazil where its name is mandioca, manioc or Brazilian arrowroot. Cassava or tapioca are English names widely used for dried-root products of the cassava plant, Manihot utilissima Pohl. or Manihot esculenta Crantz, the bitter types of cassava. Manihot palmata aipi Muell is synonymous with Manihot dulcis and Jatropha dulcis parodi, which are the sweet types. The name cassava is synonymous with yuca, rumu, manioc and manioca in Spanish speaking America and Central America. In the West Indies and the United States, it is known as cassada or cassava (originally the Haiti name). It is known as cassava or manioc in Madagascar and French speaking countries, Mandioca in Portuguese, ubi katella or kaspe in Indonesia, tpioca in India, tapioca and upi kayu in Malaysia, cassava or cassado in English speaking regions of Africa, Thailand and Ceylon. Originally, the name tapioca was derived from tipioca. Tupi is the Indian

name for the tuber meal and tipiocet for pellets (Müller et. al., 1975). In Nigeria, it is widely known as cassava, 'Ege' or 'Gbaguda' in Yoruba, 'Akpu' in Ibo and 'Rogo' in Hausa (Oyenuga, 1968).

1.2.1.3.1. Biological Characteristics

Cassava belongs to the genus Manihot of the natural order Euphorbiaceae. It was introduced from Brazil to West Africa by the early Portuguese explorers. It is now an important dietary staple and a cheap source of calories for some 200-300 million people in the tropical developing World, including Nigeria.

About forty varieties exist in the countries where it is cultivated, and these varieties fall into two groups, bitter cassava, with roots generally thickened directly from the collar in long stout tubers of about 20-50cm or up to 0.9m, and sweet cassava, with shorter roots, 10-14cm long, 2.5-5cm in diameter (plate I). The forms cultivated in West Africa probably all belong to Manihot esculenta, which is the so called bitter cassava, and the sweet cassava is sometimes classified as Manihot palmata var. Aipi, though this is properly South Brazilian. As a rule, the people recognise, according to the colour of the roots, the dark coloured as bitter. In the Northern parts of West Africa, where the people depend mainly on cereal grains, it is the sweet forms that are found almost exclusively (Dalziel, 1948).



Plate 1A = Manihot palmata (sweet cassava), whole plants



Plate 1B = Manihot palmata, root tubers

These two main species widely grown in Nigeria, namely the bitter and sweet cassava, Manihot esculenta and Manihot palmata respectively are also differentiated by the higher cyanic acid content in the bitter than in the sweet varieties. However, there are many varieties of the two species in cultivation throughout the country. Eleven high yielding varieties of the Manihot esculenta and five of the Manihot palmata have been listed for eastern Nigeria alone (Agboola, 1979). High yields and food qualities are two important considerations in the selection of varieties for cultivation. The high yielding bitter variety widely grown in eastern Nigeria which makes better gari than the sweet variety, is 'Ohupon', while 'Panya' and 'Ofopiwa' are sweet varieties liked for their yam-like qualities. In Western Nigeria, varieties such as 'Idileruwa', 'Gbokogbaala' and 'Gbayekete' are favoured by cassava farmers on account of their high yields.

The wide distribution of cassava shows its ability to thrive on most of the more important soil types found in Nigeria. However, it performs best on light alluvial soils. Its preference for well-drained soils makes its cultivation relatively unimportant in swampy locations along the coast and on the flood plains of the larger rivers (Agboola, 1979). Cassava is a hardy crop which does reasonably well on the poorer soils. It is also a crop that does well even under adverse conditions. Agriculturally, cassava is a good choice where annual rainfall expectation is 75cm but it is often chosen where rainfall is less and too unreliable

for maize, or where the ravages of birds, pests or diseases preclude grain crops (Jennings, 1970).

The crop is usually lifted after 7-18 months (Irvine, 1969) according to variety and depending on the need of the cultivator. But long-season varieties may be left in the ground for considerable periods, even up to two years.

1.2.1.3.2. Production and Yields

Cassava yields between 4 and 12 tons or more per hectare. In Africa, the average yield is about 6.7 tons per hectare (Oyenuga, 1968). Brazil is the World's greatest cassava root producer. In 1967, there were 1,914,439 hectare of cassava plantations which yielded 27,268,193 metric tons of roots, representing 32 percent of the World's production as compared with 14 percent for Indonesia, 10.4 percent for Nigeria and 8.5 percent for Congo. The total World production figure is about 83 million tons (Jennings, 1970). The World's average yield is 8.4 tons per hectare while the average Brazilian yield is about 14 tons per hectare (Magoon, 1970). The maximum yield of cassava has been calculated per hectare per day at 250,000 calories (Ugwu, 1975). As such, cassava out-yields all competitive root and grain crops and banana. Furthermore, the yield potential of cassava has not been completely exploited and one can assume that yields have not reached their limits. Thus, with the development of systems of

agriculture comparable to those used with corn and potatoes, and with industrial extraction and processing, cassava has the potential of usurping the world's starch market (Franklin, 1970).

1.2.1.3.3. Nutrient Composition

The cassava root tubers are a rich source of valuable carbohydrates (about 90 percent) but low in protein (2-5.61 percent) oil, ash and crude fibre. The peels of cassava are richer in protein, oil and ash than the peeled edible portion. The cassava root is also poor in minerals such as calcium, phosphorus and iron and in vitamins such as thiamine and riboflavin but fair in niacin content. Its protein is deficient in essential amino acids such as methionine, lysine, trypophan, phenylalanine and tyrosine but high in arginine (Oyenuga, 1968 and Franklin, 1970). New cassava varieties with up to 7.00 percent protein in the root have been reported by Beck (1971). Protein content of the leaves range between 30-40 percent (Eggum, 1970) and even between 14-69 percent (Oyenuga, 1968). Cassava leaf protein is also deficient in methionine, marginal in tryptophan and isoleucine but rich in lysine. The nutritional availability of the amino acids was found to be variable and only 60 percent of the total methionine was availeble (Eggum, 1970).

1.2.1.3.4. Cyanide Content of Cassava and Cassava Products

Both the bitter and sweet cassava root tubers contain cyanide.

Cyanide is the most undersirable constituent of the cassava plant. Its content in fresh tubers varies between 100 to 400 mg/kg with the bitter varieties containing 200 to 400 mg/kg and the sweet ones having even less than 100 mg/kg. Also, the peels were found to contain between 3-10 times more cyanide than the edible portion (Dalziel, 1948; Oyenuga, 1968 and Tewe, 1977). The cyanide is present in form of aliphatic cyanogenetic glycosides, linamarin and lotaustralin. Linamarin exists with the enzyme linase along with some free prussic acid (hydrocyanic acid). During decomposition, the enzyme linase hydrolyses linamarin, and B-glucose, acetone and more prussic acid are liberated. It is the free prussic acid that is poisonous (Oyenuga, 1968). This free prussic acid is also amenable to direct assay (Ikediobi et. al., 1980).

During the processing of cassava, such as cooking, the prussic acid is rendered inert by heat, while the remaining free prussic acid is removed in the water. Thus boiling and fermentation of the root destroy cassava root toxicity. According to Watt and Breyer-Brandwijk (1962), cassava juice, referred to as the toxic latex, is squeezed out of the root tuber then sun-dried to dissipate traces of cyanogenetic glycosides. The sap is then evaporated to a syrup thus rendering it harmless by heat. The result forms an antiseptic, known as cassareep which is used in meat preservation.

The symptoms arising from eating improperly prepared cassava root tubers are nausea, vomiting, abdominal distention, respiratory

difficulty and collapse. If large amounts of raw cassava are consumed, it causes the same symptoms as above including burning feeling all over the body and instanteneous death. If smaller amounts are consumed, the person experiences a short period of stimulation with excitement and convulsions followed by depression and death. Over a long period of consumption, cassava foods cause goitre, cretinism and tropical ataxic neuropathy with mental retardation (Osuntokun, 1973). At post-mortem, the characteristic finding in cyanide poisoning is bright red venous blood.

When the peeled portion (pulp or edible portion) contains less then 50 milligrams of acid per kilogram of the freshly grated cassava, the cassava can be taken as harmless to the consumer. But a concentration of between 50 and 80 milligrams may be slightly poisonous, 80-100 milligrams is toxic while concentrations above 100 milligrams per kilogram of grated cassava are fatal (Oyenuga, 1968). A prussic acid dose of 2.042 mg/kg body weight for cattle and 2.4 mg/kg body weight for sheep had been reported to be fatal. These values correspond to 0.817mg HCN and 0.9 26mg HCN for cattle and sheep respectively. Obioha (1972) had reported that some sheep and goats had died within minutes of ingesting some Nigerian cassava varieties. Peels of cassava roots, particularly of the bitter varieties, are widely fed to domestic sheep and goats in the cassava - producing areas of southern Nigeria (Oyenuga, 1968). But during the preparation of gari, farina de mandioca, which is similar to gari, and tapioca, the cassava is usually peeled first

before washing, soaking and grating, all of which help to reduce the cyanide content to a considerable extent. Apart from peeling, washing, soaking or steeping, grating and pressing out the juice, sun-drying, heating and cooking, long periods of storage, silage preparation and fermentation also help to remove the cyanide and thus detoxify cassava and its products.

1.2.1.3.5. Uses of Cassava and Cassava Products

It seems cassava will continue to be important as a source of food for people because, with up to 35,000 kg per year, cassava can and does alleviate caloric hunger (Franlin, 1970). In Brazil, a diverse number of foods and drinks are prepared from cassava starch, Cassava flour (Farina) must be incorporated into every loaf of bread and as supplement of many foods, by law. In addition cassava flour is used in a variety of paste products such as macaroni and spaghetti (Edgar, 1970).

Apart from serving directly as food items in many human meals, cassva is used for other purposes as listed below:

1. In the manufacture of cassava starch where the starch is used for making many products such as fermented starch biscuits (biscoits de polvilho) and cheese bread (pas de queijo).

2. Cassava is used to meet local requirements for glucose and starch in Uganda. In some other countries dextrins and

pregelatinised starch are made from cassava in small commercial quantities. Cassava starch derivatives such as sagos and tapioca are also important in Brazil.

3. Beer is manufactured from cassava root tubers, for example, in Brazil ethyl alcohol production is famous.

4. Cassava is employed in the manufacture of many types of flour known all over the World, for example, farina and gari.

5. Cassava is used to make certain food products such as beijus (Solid product), tabaca (drink) and tucupi (sance) in Brazil.

6. Cassava leaves are used as a vegetable called kisamvu in East Africa. The leaves are used as vegetable in many parts of the world in human foods and relished by livestock. In Southern China, the silkworms are reared on cassava leaves.

7. Cassava stem is used in the production of cellulose by-product.

8. Cassava is an important feed component of pig, poultry and cattle rations in many parts of the world. Cassava is used to either partly or wholly replace maize or rice in the various diets (Obioha, 1975).

Since cassava based - diets are generally low in protein, they require supplementation, with some amino acids. Currently, most supplementation is done with oilseed cakes. And provided the ration is adequately textured, preferably pelleted, up to 60

percent dried cassava can be used in poultry and swine diets (Nestel et. al. 1975 and Nestel, 1977). The possibility of also improving the nutritive value of cassava feeds by fermenting with yeast, fungi and bacteria has gained considerable ground (Franklin, 1970).

1.2.1.4. Edible Aroids (Cocoyams)

Two species of cocoyams, namely, Colocasia esculenta Schott - Holl., also called 'eddas' or 'eddoes' or 'dasheer' (Trinidad var.), the taro cocoyam and Xanthosoma sagittifolium Schott-Holl. the tannia cocoyam, also known as 'taye or tayonne' in Guyana and 'yautia' in Antilles, are the most important aroids known. Both taro and tannia cocoyams are common food staples in the South Pacific Islands of the West Indies and, the Philippines. The taro cocoyam is also native to Tropical Asia and Malaya as well as to Eygpt and to Ghana in West Africa (Dalziel, 1948). According to Oyenuga (1968) both taro and tannia were imported into Nigeria from the West Indies, tannia being a later introduction. In the Arab countries, taro is popularly called Kolkas. Tannia is gradually replacing Colocasia in Nigeria and the Cameroons.

1.2.1.4.1. Biological Characteristics

Tannia is distinquished from taro by its sagittate leaves which are dark green in colour with free basal lobes while taro has pale green peltate leaves with joined basal lobes (plate II). Both plants



Plate IIA = Colocasia esculenta (taro cocoyam) whole plants



Plate IIB = Colocasia esculenta corms and cormels as sold in Zaria markets.

grow to a height of about 10-15cm and possess very large leaves. They produce stem tubers called corms and cormels but those of the tannia are larger and harder. Tannia can usually be pounded into fufu unlike taro which does not make fufu, a common practice in Ghana. Tannia tubers do not possess the irritating principle caused by calcium oxalate crystals found in most varieties of taro. Tannia gives higher yields than taro, and succeeds mostly in regions where there is a prolonged rainy season while taro is is found in drier areas (Dalziel, 1948).

1.2.1.4.2. Nutrient Composition

Tannia and taro are a fair source of energy and an excellent source of minerals and vitamins. Both contain similar nutrients. Their corms contain starch and are used like yams, cassava and potatoes except that they contain lower carbohydrate, fat and fibre values but higher protein values (up to 8 percent). They also contain higher amounts of ash, minerals and vitamins. Their low energy and protein valuesare corrected by consumption of additional foods and by the use of their leaves as a vegetable, since their leaves are fairly rich in protein (about 20-25 percent). The mineral composition of tannia is slightly higher than that of taro though taro is superior in protein content. Taro has more calcium and phosphorus than tannia. The minerals in tannia are evenly distributed throughout its tissues while they are concentrated in the peels of the taro cocoyam. Both have low fibre content. The

proteins have fair supplies of essential amino acids which are low in histidine and lysine (Oyenuga, 1968). The peel are richer in oils than the inner tissues. The leaves have a higher nutrient content than the corms which are consistently lower in oils, protein, fibre and ash. Also taro leaves have more nutrients than tannia leaves.

1.2.1.4.3. Biologically Toxic Substances

Aroids are highly irritating due to the presence of raphides of calcium oxalate. This is the cause of irritation to the mouth when the leaf is chewed. The cultivated stem corms when boiled or roasted lose this acridity. The corms also contain a goitrogenic substance. A highly toxic acid sapotoxin has also been isolated from the plant, Colocasia. The toxicity is so high that 0.1mg injected into a rat produces instanteneous death (Jones, 1934). The chief post mortem finding is marked congestion of the adrenal bodies. The sapotoxin haemolysis blood in vitro, producing haematoporphyrin. The toxic effects of Colocasia sapotoxin and of similar sapotoxins from other plants such as Alocasia and Xanthosoma, are neutralised to some extent by the inclusion of cholesterol-containing foodstuffs in the diet. The administration of raw adrenal glands has also proved curative in Colocasia poisoning.

Although, it contains sapotoxins the leaf is less toxic than the tuber (Oberdoffer, 1939 and 1940). In addition to the seasonal

variation in toxicity, considerable individual human or animal variation in susceptibility to the toxin has been noted and the consumption of moderate amounts of Colocasia rarely produces really acute effects. It is also interesting to note that the consumption of Colocasia has a relationship to the incidence of dental caries. For when cereal grains, which has a potential alkalinity of 6 - 10ml of N alkali daily, is taken the carbondioxide combining power of the blood plasma is low (50-60 vol percent), the urinary acidity is high (pH 5-6) and certain diseases including dental caries show a high incidence but if roots and tubers are the source of carbohydrates in the diet, the potential alkalinity is 36-45ml N alkali daily and the incidence of these diseases including dental caries are reduced (Jone 1934).

The presence of sapotoxins in aroids is also associated with the abnoxious effect of intensifying leprosy (Watt and Breyer - Brandwijk, 1962). Leprosy lesions in four Macacus-rheus apes were produced by feeding them with raw Colocasia. The toxicity of Colocasia has a marked seasonal variation, being usually highest at the end of the dry season. A glomerulo-tubular nephritis and a marked degeneration of the adrenals are the essentials of the toxic action. Curiously enough, the tuber has proved more toxic in Trinidad than in West Africa. The reasons for these differences are not well defined, although soil and climatic differences have been suggested (Clark, 1936). It has also been observed that there is a prevalence of nephritis in populations using Colocasia as a foodstuff.

1.2.1.4.4. Uses of Cocoyam and Cocoyam Products

Most people using the corms for food prepare them like potato, yam or cassava by peeling them first, then slicing or dicing them before boiling, baking or roasting, and eating them either with fish or meat. The leaves and petioles are prepared like spinach in the Philippines, West Indies, Indonesia, India and Pakistan and Thailand. After removing the main ribs from the young leaves, the leaves are utilised as pot-herbs. The leaves are also eaten after cooking them with soda. The acridity felt after chewing the leaves can be relieved with lime juice. In Hawaii and Rapa Islands, taro is prepared into poi (Standal, 1970). Poi (starch) preparation involves pressure cooking the corms, washing, peeling, grinding and passing the paste through a series of strainers, the final one having opening of 0.5mm in diameter. The resultant poi has a pasty texture and is grey-brown in colour. In Hawaii, it is sold commercially in plastic bags, jars or cans. Poi is widely accepted in Hawaii and elsewhere in the United States of America. Poi has no gluten or gluten-like substances, thus it has been recommended for substitution in infant food, especially where the infants are allergic to celiac disease caused by cereal feeding (Pena, 1970). In addition, dietary carbohydrates, particularly sucrose, enhances the levels of serum gluceride and cholesterol in humans. Hence the effect of poi carbohydrates on tissue lipids is of great

scientific interest since the starch of aroids contain predominantly amylose of 490 glucose units and small amount of amylopectin of 22 glucose units (Standal, 1970). In East Africa, cocoyam corms are used as a poultice for snake-bite while the leaf and fruit are used as a rubefacient. The cocoyam plant is also used as antiseptic, stimulant and rubefacient and for application to scorpion stings. In Brazil, the plant is used as an anti-helminthic (Watt and Breyer - Brandwijk, 1962).

1.2.2. The Quest for Protein-Rich Foodstuffs

The need to satisfy the nutritional requirements of a significant part of the world population, namely, the developing nations, can not be over emphasised. In most cases, this nutritional insufficiency is attributed to protein unavailability. Since the lack of an economic source of animal protein is acute, vegetable or plant protein is increasingly being resorted to inspite of the fact that the best quality proteins come from animal sources (Sikka et. al., 1979).

According to the USA National Research Council definitions, foodstuffs or feed-stuffs that in the dry state contain 20 percent or more of protein are classified as protein supplements while those that contain more than 18 percent crude fibre are classified as forages and roughages. These that contain less than 20 percent of protein are classified as energy feeds or concentrates (Jurgens, 1978).

A supplement is usually intended to be fed undiluted as an addition to improve other feeds, separately available or further diluted and mixed to produce a complete feed. On the other hand, a concentrate is a feed used together with another feed in order to improve the nutritive balance of the total feed and is intended to be further diluted and mixed to produce a complete feed. In commerce today, the term 'concentrate' has been almost universally used for commercially prepared supplements (Crampton and Harris, 1968). In this thesis, the term concentrate is synonymous to supplement.

There are two main sources from which protein supplements or concentrates can be prepared, namely, animal and plant or vegetable sources.

1.2.2.1. Protein Supplements of Animal Origin

Protein supplements of animal origin are derived from meat packing or rendering plants, from surplus milk or milk by-product or from marine sources. These animal protein supplements include tankage, meat scrap, blood meal, milk products, poultry by-product meal, hydrolysed poultry feather meal, fish and shell fish meal, fish solubles, animal wastes, urea and biuret. Proteins of animal origin are usually employed to improve the total protein of basal feeds, but in addition, contribute a mixture of amino acids different from proteins of plant origin. Whereas, plant proteins

are usually seriously deficient in lysine, animal and fish proteins are relatively rich in this essential amino acid though they may be short of sulphur amino acids and tryptophan. The animal supplement may be included at 5 to 10 percent of the diet as a replacement for plant protein (Jurgens, 1978).

Generally, proteins from animal sources have a better quality than proteins from vegetable origin. Animal proteins usually have a higher biological value than plant proteins. Their biological values are closer to that of egg protein which is considered to be the ideal protein in practical feeding (Block and Mitchell, 1946 and FAO, 1970). An ideal protein is one containing all the essential amino acids in sufficient amounts to meet requirements without any excess. The egg protein is considered to be equivalent to this ideal protein. Furthermore, the BV of egg protein is close to 100 percent (actually 98 percent) than any other protein.

In animals, about 22 percent of the dry matter is protein. Most plant sources contain less protein, for example, cereals have between 13-18 percent and cassava, which is a major foodstuff in certain areas, is as low as 1.3 percent in protein content. Among legumes and oilseeds, soybean contains over 30 percent protein, and among other plant sources, only Chlorella and Torula yeast contain higher concentration of protein (50 - 80 percent). Furthermore, animal proteins are more savory and more palatable than any other protein source. Animal proteins also contain certain

vitamins, such as vitamin B_{12}, and minerals which are not present in vegetable proteins. In addition, there are less harmful ingredients since the aminal acts as an efficient filter removing most of the toxic and interfering materials from its own food, either by detoxification or elimination.

But because animal proteins are costly and are not produced in sufficient amounts, it is of utmost importance to develop equally high quality protein concentrates from plant source (Altschul, 1962).

1.2.2.2. Protein Supplements from Plant Origin

Since proteins from animal sources are costly and not available in sufficient amounts and the world's populations where protein deficiency is prevalent subsist almost entirely on vegetable diets, diets could be formulated from appropriate plant mixtures to meet requirement for both man and livestock.

For example, corn protein is low in lysine while soybean protein is high in lysine. So if the right amounts of soybean and corn are mixed together, all the essential amino acids required by either a pig or rat may be provided without further supplementation (Maynard et. al., 1979). This sort of experimentation has in fact

been done successfuly in several places for example, soyogi mixture produced by the Federal Institute for Industrial Research, Oshodi, Lagos, Nigeria. Soyogi is a food mixture consisting of corn and soybeans. It meets the nutrient requirements of children. Another all vegetable mixture of high protein quality is incaparina produced by the Institute for Nutrition of Central America and Panama (INCAP). 'Incaparina' consists of 29 percent whole ground corn, 29 percent whole ground sorghum, 38 percent cotton seed flour, 3 percent Torula yeast, 1 percent calcium carbonate and 4500 I.U. of vitamin A per 100 grammes. This product is sold for 3 cents for a 75 gramme bag sufficient for 3 glasses, when reconstituted with water, with a protein content comparable to that of a similar amount of milk. It is produced commercially at low cost and requires little or no readjustment in the eating habits of the native families (Wislon et. al., 1975).

Such high protein foods, beverages and textured foods for humans have been reported by Altschul, (1969 and 1970). They have the advantages of (1) high protein content therefore adequately satisfying amino acid requirements for humans, (2) being readily available, (3) cheap and (4) acceptable to the people.

Plant protein supplements or concentrates come from three different sources, namely:

1. Seed proteins, which are obtained from seeds. The oilseeds are the main protein suppliers. After oil extraction, the resultant oilmeal or cake that remains is normally rich in protein. This meal or cake is usually fed to animals.

2. Vegetable proteins are also prepared from forage crops, also referred to as fodder grasses, and from leaves of plants. When leaves or leaf extracts are made into leaf meals and leaf protein concentrates respectively, they are included in animal feeds are required.

3. Micro-organisms such as fungi (yeast), algae and bacteria are grown and cropped for inclusion in animal rations. These are very high in protein (80 - 85 percent) Robinson, 1971; Worgan, 1976; Walterworth, 1977 and Edwardson et. al., 1981).

1.2.2.2.1. Leaf Protein

The leaf is usually highly hydrated and consequently, its protein concentration is correspondingly low. Protein of fresh leaves make up less than 5 percent of the total fresh weight as compared to seed protein which may make up to 40 percent or more of the seed weight (Bondi, 1958). The essential amino acid content of leaf proteins are comparable in amounts, with some exceptions, to those of casein. Leaf protein preparations obtained from different plant species do not show great difference in their amino acid content. Relatively low cystine and methionine values

were found in protein prepared from leguminous forage crops compared with those reported for the other plant families. The amino acid compostion of the bulk protein of the leaves for any one species varies little with age of plants, with manurial treatment and with climatic conditions (Bondi, 1958).

On the other hand, the protein content of green plants and that of the leaves, in particular, is strongly influenced by growth conditions and the state of the plant. The protein deceases greatly during growth and development. For example, it was found that the Nigerian guinea grass had a crude protein content of 12.3 percent at four weeks old but by the tenth week, it had decreased to 8.6 percent (Ademosun, 1973). Similiarly, the Italian rye grass contained 18.5 percent protein at two weeks but 12.1 percent at six weeks (Bondi, 1958).

The leaf is richer in protein than the stem and the proportion in leaf to stem changes with age. Other factors such as season of growth, time of day of cutting and variations in soil moisture and temperature influence the protein content of green plants. An increase in the protein content of forage crops, especially at later stages of growth, may be observed from nitrogenous manuring. For herbivorous animals, leaf proteins, normally present in green forages, form a considerable part of the animal protein ration. Most forage crops belong to two plant groups, the grasses and the legumes. The legumes usually have a higher protein content.

The preparation of leaf protein concentrates (LPC) or leaf meals involves drying of leaves in order to dehydrate them. After that the protein can then be extracted. It was also found that the digestibility of leaf proteins for rats and chicks was reduced to about half after drying (Thompson, 1958). Leaf proteins are used almost entirely as ingredients for mixed feeds. A few attempts have been made to feed them directly, as in the supplementary feeding of sheep and cattle which have been on poor range for an extended period. The material is ordinarily pelleted for this purpose and has given surprisingly good increases in feed utilisation with animals feeding on forages which may have been dry for several months. The extra vitamins and minerals improve the adequacy of the diet and also provide a better medium for the ruminal flora, thus further aiding in the digestion of fibre to yield more energy.

About 60 percent of the total leaf meal production used in mixed feeds goes into poultry feeds, 10 percent into cattle and dairy feed, 10 to 15 percent into hog feed and the remainder into rabbit, dog and other small animal feeds. A specially processed alfalfa leaf meal is included at a low level in 'Pablum', a widely used infant cereal (Thompson, 1958).

1.2.2.2.2. Seed Proteins

The two sources of seed proteins are mainly grain cereals and grain legumes.

The grain cereals are all monocotyledonous seeds. They contain only comparatively small amount of protein, approximately 10 - 15 percent. Nevertheless, cereal proteins are very important nutritionally because they form a great part of the daily food of men and farm animals. Though cereal grains are not usually considered as protein food, they are often the chief protein source in the diet.

Considerable fluctuations in protein content and composition of grains may result from varietal differences and environmental conditions (soil, rainfall and location). Various parts of the cereal grain kernels contain different amount of protein. For example, wheat germ contains 30.9 percent, bran 16.7 percent, and the endosperm 14.25 percent protein. After removal of starch or oil from the seeds, the residual meals of these seeds are usually rich in protein and can be used as concentrates in feed mixtures. But as a class, cereal proteins do not have as high biological value as do the proteins of legumes, oilseeds and nuts or animal proteins. This is because essential amino acids, such as lysine and tryptophan, are low and as such, limiting. Cereals as suppliers of amino acids for monogastric farm animals (pigs and poultry) and humans may be complemented by foods which are more efficient as sources of the limiting amino acids, lysine and tryptophan (Pondi, 1958).

The dicotyledonous leguminous seeds are much richer sources of proteins than the cereal seeds, hence oil seeds are essentially protein suppliers for man and animals. Oilseeds, which contain on

average, 20 - 30 percent crude protein, are used primarily as a food and only a small quantity is for industrial purposes. The larger seeded legumes, such as dry beans, peas and lentils, which contain 22 to 25 percent protein, play some important role in the supply of proteins for man and animals.

Because of their large oil content, oilseeds play a major economically important role. But if they are looked at instead from the point of view of their protein content, then processing operations can produce new sources of concentrated protein for men and his animals. Already, large populations of monogastric animals such as poultry and swine have been fed successfully on all vegetable sources of protein. And oilseeds including seed legumes, furnish almost half as much protein as do the major cereals, but most of the protein from oilseeds now goes to feeding animals other than man (Altschul, 1962).

The use of beans and peas of one kind or another is almost universal. Although, many of these beans and peas can be eaten green and immature, such as peas and kidney beans which are usually eaten in the USA and Europe, they are not large contributors of protein to the diet. They become important for their protein when the mature dried beans are eaten. These can be made into flours in many countries. Nearly all kinds of diets are prepared from them in the home. They are soaked in water until they have absorbed the maximum amount, a process that loosens the outer skin

so that it can be rubbed off easily if desired and cooking for an hour or so makes them soft and floury. Most beans have a distinctive flavour which gives a welcome change from the flavour of the cereal or starchy staple. They can be spiced or salted. Some contain fat as well as protein and in more than one way therefore, they take the place of the animal protein part of the meal. Although, it is more usual for them to be served as a separate side dish, they are sometimes cooked together with the staple, meat and fish.

Peas and beans are among the outstanding sources of vegetable protein available to man. They supply a valuable complementary food for the daily needs of man and domestic animals and play a major role in the improvement of soils (Deschamps, 1958). Beans vary considerably in disgestibility and therefore in the degree to which they are suitable for young children and growing animals. It has been reported that the winged bean has an *in vitro* digestibility of 67.3 percent due to trypsin inhibitors (Ekpenyong *et. al.*, 1979). Other beans which have been studied in detail and found to be protein rich as well as promote growth include soybeans (Cravens *et. al.*, 1958; Altschul *et. al.*, 1962, 1969 and 1970; Fetuga, 1974; Jurgens, 1978; Modic *et. al.*, 1981 and Offiong, 1984), the lima bean (Aletor, 1983), cowpeas (Joao *et. al.*, 1979) and the broad beans (Griffiths, 1979 and Al-Nouri *et. al.*, 1980). Oilseed meals which are well known high-quality protein concentrates that have been successfully used in

animal experiments over the years include cotton seed meal (Altschul et. al., 1962, 1969 and 1970; Hassan, 1974; Sayed, 1979; Horn, 1981; Gad et. al., 1981 and Pigg, 1981), lin seed meal (Peterson, 1958 and Jurgens, 1978), sunflower meal (Clandinin, 1958), rape seed meal (Vloss et. al., 1976; King et. al., 1977 and Fenwick, 1982), mustard seed meal (Christain, 1956), safflower meal (Kneeland, 1958), groundnut meal (Rosen, 1958; Nesbitt et. al., 1963; Lyso. 1966, Oyenuga, 1968 and Fetuga, 1974), sesame meal (Dean, 1958; Caldwell,, 1958; Altschul, 1969 and Jaconda, 1975), coconut oil meal (Curtin, 1958 and Oyenuga, 1968), cocoa by-products (Oyenuga, 1968 and Devendra, 1981) and palm kernel meal (Collingwood, 1958; and Fetuga, 1974).

Since most of the above mentioned protein rich seeds are being heavily patronised by humans and they are not always available for use, attention should be turned to other lesser known sources such as seeds of tree legumes which are also protein rich and contain good amounts of essential amino acids. In the present research, the seeds of two tree legumes namely, the African locust bean (Parkia) and Tamarindus were investigated.

1.2.2.2.3. Parkia Clappertoniana Keay (African locust bean - English; Dorowa-Hausa, Donwa-Zaria).

1.2.2.2.3.1. Biological Characteristics

The African locust bean tree is fairly widely distributed all

over the natural grassland of Northern Nigeria. It is a spreading tree of medium size, with compound leaves and numerous leaflets. It is often leafless when in flower (plate III) and may be defoliated by caterpillars. The abundant leaf-fall is a valuable soil improver, rich in nitrogen and ash. The fruits are represented by bunches of pods, which hang in clusters. The immature pods are usually bright brown in colour while the mature pods are dark brown. Each pod varies between 15 - 25 cm in length according to soil fertility, contains a yellow dry powdery pulp, inside which are embedded a number of dark brown or black seeds (plate iv). The yellow pulp is a soft substance and can be separated from the seeds by sifting after drying (Dalziel, 1948 and Oyenuga, 1968).

From feeding experiments Fetuga (1974) concluded that when rats were fed diets with whole seeds and seed nuts, they did better on the seed nuts than on the whole seeds though, the seeds with or without testa, cooked or uncooked did not support growth, showed low NPU and BV values. Supplementation with methionine and tryptophan greatly improved growth, NPU and BV values. Umoh and Oke (1974) recorded growth in rats after feeding the Chloroform extracted bean seeds.

1.2.2.2.3.2. Nutrient Composition

The meal from the fuit is rich in assimilable carbohydrates. The fruit contains little fat (0.6 percent) and protein (5.0 percent), about 41.2 percent husk, 33.4 percent powdery material and 25.4



Plate IIIA = Parkia clappertoniana (African locust bean) tree in the month of December. Though leafless, it is in flower.

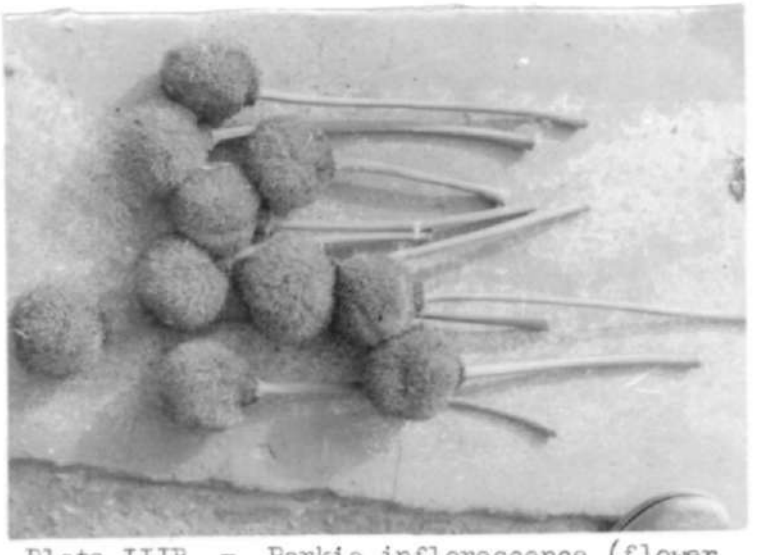


Plate IIIB = Parkia inflorescence (flower heads).

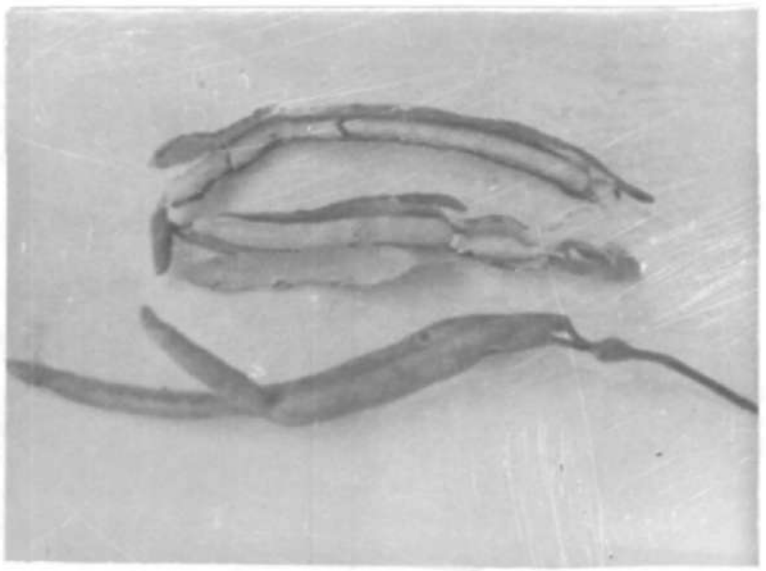


Plate IVA = Pods of Parkia



Plate IVB = Parkia seeds, after opening the pods.

percent seeds. The seed has a high fibre content (18.3 percent) and is rich in phosphorus and calcium (Woot - Tsuen, 1968). The seed is rich in protein. Reported values vary between 30 percent protein for raw seeds to 40 percent in cooked and fermented seeds and seed nuts', 2-13 percent fat; 4-9 percent crude fibre and 2-5.3 percent ash (Dalziel, 1948; Oyenuga, 1968; Fetuga, 1974; Eka, 1980; Obodo, 1982 and Okeoma, 1984). Busson (1965), Fetuga (1974), Eka (1980) and Okeoma (1984) reported deficiency in the essential amino acid content of the protein. The reported low values for sulphur amino acids such as methionine and cystine, also for histidine and tryptophan but high values for lysine. The bark of the tree contains 12-14 percent tannin and a red brown colouring matter (dye) absorbable by animal hides (Dalziel, 1948).

1.2.2.2.3.3. Uses of the African Locust Bean

Almost all the parts of the African locust been tree are useful. The bark of the lower part of the tree is often cut away for medicinal use. An infusion of the bark is regarded as a tonic. A concoction of the husks is taken cold as an astringent for diarrhoea. In some districts, the leaves are collected for use as manure. Sometimes the husks are macerated in water, or boiled and allowed to ferment, refuse from the blacksmith's forge and pods of Acacia arabica are commonly added, and then used as a fish poison. Also, the pods themselves may be thrown into the water as fish bait (Dalziel, 1948). The leaves mixed with cereal flour makes

a food called 'balam bantani in Hausa. A sauce, called 'ashnyu' by the Jukuns, said to be of Hausa origin, is commonly made from the leaves, boiled, strained, mixed with wood-ash water and left to stand for two days. The mixture is then partially sun-dried, pounded and made into balls. The red flowers are called 'tutu', 'bututu' or 'tuntu', in Hausa. They are sucked by children for the sweet juice, 'badano' (Kano). Beehives are usually placed in the tree branches because of the juice. The pods form the most nutritive part of the plant. Its soft yellow meal is sold as powdered biscuit and is a valuable food used with rice or other cereals or with meat, or in soup, or made up into cakes to keep for sometime. The yellow mealy pulp is sweet to the taste and the biscuit from it is called 'dorowa' (Hausa). A drink made from it is called 'bololo' and one made from the pulp along with tamarind water is known as 'dagwadago', 'dangwami' or 'dagale', also 'gwaggo' and 'gagu' (Zaria). In Ghana, water is usually added to the pulp, to make a paste. The mealy pulp is said to be unwholesome for people when eaten before the early rains, causing symptoms of nausea, vomiting and collapse. However, the whole fruit is said to be a good fodder for domestic stock (Dalziel, 1948). But fruit portions fed to pigs and poultry should not be too high in fibre since these animals have limited ability in fibre digestion. Usually the seeds are boiled for 24 hours to soften the seed coats, pounded, washed several times to remove the broken

shells. The kernels (nuts) are boiled to form a paste and then set aside for 2-3 days to ferment. Various names are given in Hausa to these fermented seeds. After fermentation, they are made into cakes or balls called 'daudawa' or 'daddawa'. The resultant rather strongly smelling blackish article is used as food and seasoning, commonly as a basis for soup and as it keeps well, it is an important item of Hausa itinerant trade, both for personal use and for sale. The odour is destroyed by frying or roasting, and its place in culinery economy is much the same as that of cheese amongst Europeans, as a concentrated food, used also as a seasoner. A Hausa food called 'kwa'do' consists often of 'daudawa' to which the leaves of Crataeva Adansonii with salt and condiments are added. In Togo, the seeds are ground to a fine meal and macerated in water to make a sort of gruel to be taken as a refreshing drink. The seeds are said to be capable of rendering foul stinking water potable (Dalziel, 1948).

1.2.2.2.4. Tamarindus indica Linn-Holl. (The Indian tamarind - English Tsamiya - Hausa).

1.2.2.2.4.1. Biological Characteristics

The tamarind grows spontaneously throughout the savanna grass-lands, growing particularly well in the neighbourhood of towns and villages, but elsewhere, it is planted. It is probably originally African and introduced long ago into India, and not vice versa

(Duke et. al., 1981). This is because the pulp (African variety) is rarely so well developed and juicy as that of the Indian variety showing that in the latter country, the tree must have been improved by selection. It often forms a dense symmetrical crown with branches all round to 75-100 cm from the ground. There is abundant leaf-fall and usually almost no undergrowth beneath it. In damp weather, the leaves are said to have a corrosive action on fabrics on which they fall. Natives in India object to sleeping under a tamarind tree, attributing to it harmful acid exhalations. It is also frequently seen growing on or beside ant hills, the structure of which is probably favourable to its root system (Dalziel, 1948).

The tamarind tree can live long, more than 120 years. It is a large evergreen tree, spreading and open, to about 33m tall to 8m in circumference (plate v). The bark is brownish-grey and looks shaggy. The leaves are 5-12 cm long, abruptly pinnate with 20-40 pairs of leaflets which are narrow, oblong and rounded on both ends. The leaflets are 1.3 - 2 cm long. The tree bear flowers which have racemes at the end of the branchlets. The calyx are 1.3 cm long. There are 4 sepals which are ovate - lanceolate, acute tip, 3 developed petals. The fruit is a brown starchy curved pod, 5-8 cm long and 2.5 cm wide, somewhat flattened, constricted at intervals with a thin brittle shell containing a soft brownish pulp traversed by a few strong branched fibres (plates V and VI). The furit contains 1-2 seeds per pod, ovate to oblong, truncated at both ends, glossy and smooth as well as flattened.



Plate VA = Tamarindus indica tree



Plate VB = Tamarindus indica (Tamarind fruit pods



Plate VIA = Individual pods of Tamarindus



Plate VIB = Tamarindus seeds from several pods.

It starts flowering by April - May in the Northern hemisphere and the fruits ripe by October - November. The largest fruits have the best flavour. The fruits taste sour sweet. For planting, the seeds are soaked for 4-5 days and then planted 4 cm deep in nursery beds. By 9-10 months, the young plants have grown to between 60-70 cm tall and can be transplanted during the rainy season with manure. A mature tree can yield 80-90 kg of prepared pulp (Duke et. al., 1981

1.2.2.4.2. Nutrient Composition

The leaves, inflorescence, fruits, pulp, whole seeds, seed testa and seed nuts (Kernel) have all been analysed chemically for nutrient content and found that the inflorescence, fruit and leaves have varying protein content of between 1.6 percent in the inflorescence to 5.0 percent in the dried fruits. The highest protein content was recorded in the seed kernels to be between 15.4 - 22.7 percent (Duke et. al., 1981) while Obode (1982) obtained 37.91 percent protein in the seed nuts. The tamarind have low ash and fibre content in the seed nuts but high fibre in the leaves, fruits, whole seeds and seed testa. Mineral contents include sodium, calcium, potassium, phosphorus and Iron while vitamins such as carotene, thiamine, riboflavin, niacin and ascorbic acid were reported to be present in small amounts (Duke et. al., 1981). No data seem to exist on the amino acid content of the protein.

1.2.2.4.3. Uses of the Tamarind

The fruit is sold in markets in the form of cakes or balls of the pulp pressed together with the seeds. This may be used without special preparation, or the pulp may be boiled and concentrated to a paste, which is then dried in the sun and made into balls. The laxative properties of the fruit - pulp are recognised, and it is also used as a food seasoner in various ways, boiled with cereal pap, it is drunk for constipation. It is also prepare as a drink, to which onions are added. A pleasantly acid drink is made by a cold infusion of the pulp with sugar or honey and water, left to mature for several days. The pulp itself is pleasant to suck to relieve thirst on a journey. Its acidity is due to tartaric acid, the amount of which averages, in water-free material, about 9 percent with 7 percent bitartrate of potash, and generally some malic acid but no citric acid. It is reputed in India, from old times, as anti-scorbutic like lemon juice, and is much used in chutneys, curries, pickles, etc. (Dalziel,1948).

In Senegal, a sweet meat called bengal in Wolof, is made from the unripe fruit. As a laxative, it may be taken along or mixed with lime juice, honey, etc. It is believed to be a preventive of fevers and sun-stroke. The best form for internal use is the boiled and evaporated pulp which, when mixed with water, in which it is partly soluble, is widely used all over the Sudan specifically for fever. The flowers are made into a sort of salad, called 'fate

fete', along with 'daudawa' butter, salt and chillies. The leaves are also put in soup. The bitter infusion of the pods is used to cook cereal foods and as a drink for women after childbirth. A concoction of the bark is used as an astringent in diarrhoea, and as an eye lotion. In East Sudan, the bark is used as a tonic and febrifuge and the root to cure chest complaints. The kernel (nuts) of the seeds contain an oil and are edible, though not commonly eaten unless in scarcity. The hard shell (testa) must be removed after roasting or boiling and the kernels (nuts) made into a meal mixed with cereals. The oil is suitable for use in varnishes (Dalziel, 1948).

In Latin American countries, the tamarind is cultivated for the pulp in the fruit which is used to prepare a beverage and to flavour confectioneries, curries and sauces and made into preserves and syrups. Fresco de tamarindo is a favourite beverage which is bottled commercially. It is an ingredient in sweet and sour sauces and in chutneys. The flowers, seedlings and even leaves are used as vegetables in curries. The bark is chewed as a masticatory. The seeds can be soaked, boiled or roasted, then peeled before consumption as a starchy food-stuff. The pods are usually added to pots to detoxify poisonous Dioscorea dishes and to deodourise fish dishes. In India, the seeds are used for food and as carbohydrate for sizing cloth, paper and jute products and a vegetable gum used in food processing. The wood is hard and durable and is therefore good for making tools, production of good

grade of gun powder and charcoal. The pulp is also used as an antiscorbutic. In Eritrea the pulp is also used to cure dysentry and malaria; in Indonesia for hair ailments; in Madagasca for worms and stomach disorders; in Mauritius, as a liniment for rheumatism; in Kenya for snake bite; in Sri Lanka, for jaundice, eye diseases and ulcers; in Cambodia for conjunctivitis, and in Brazil as a diaphoretic, emollent or purgative medicine and for treatment of haemorrhoids. The seeds are also used to treat dysentry and the bark as an antiasthmatic, antiseptic, asperient, for apoplexy, febrifuge, hangover and leprosy (Duke et. al., 1981).

1.2.2.5. Anti-nutritional Factors in Leguminous Seeds

Just as some biologically toxic substances found in root and tuber crops tend to limit their use and acceptability as animal feeds (Oyenuga, 1968 and Cerning-Beroard et. al., 1976), Leguminous Seeds naturally contain certain inherent or endogenous toxic subtances which may at low levels of concentration adversely affect feed intake and palatability and feed conversion. At higher concentrations these toxic antinutritional factors may even result in the death of animals (Cookerell et. al., 1975).

For example, traces of cyanide can be demonstrated in all plants and it is found mainly in form of cyanogenetic glycosides. Cyanogenetic glycosides are compounds which liberate hydrocyanic acid (HCN), one or more molecuoles of sugar and with one exception,

an aldehyde or ketone on treatment with dilute acid or the appropriate hydrolytic enzymes (Conn, 1969). Conn, (1969) also reported that cyanogenetic glycosides are derived from closely related amino acids such as tyrosine which is effectively converted to dhurin (present in young stems of sorghum); phenylalanine into prunasin, valine into lotaustralin. Lotaustralin, Linamarin and prusic (hydrocyanic) acid are present in cassava. Various species of lima beans (Phaseolus lunatus) contain hydrocyanic acid (10-312 mg/100g) in various concentrations. It is also present in lin seed (Peterson, 1958).

Hydrocyanic, oxalic and phytic acids have been reported to be present in the African locust bean seeds in small non-toxic amounts. The oxalic and phytic acids could act as anti-nutritional factors by forming insoluble salts with minerals thereby preventing their effective utilisation (Eka, 1980). Also, hydrocyanic, phytic, malic, citric and tartaric acids have been reported in tamarind seeds (Duke et. al., 1981). The cultural practice of fermenting both the African locust bean and tamarind seeds is said to have two advantages, improving the nutritional qualities as well as reducing the contents of these acids in the seeds (Eka, 1980). Eka (1980) suggested biological evaluation experiments to be performed using the African locust bean seeds since not much research has been done in this area. Apart from prusic acid in lima beans, legumes contain other anti-nutritional factors and toxins such as allegens in broad beans (Vicia faba) which cause

favism characterised by haemolytic anaemia (Larkin, 1953). Toxic principles in Lathyrus, Lupinus and Cicer species were reported to be poisonous to rats which showed pathological conditions such as skeletal lesions, retardation of sexual development and various degrees of paralysis, The diseases were variously called lathyrism, cicerism or odoratism accordint to the type of beans fed (Dupuy and Lee, 1956 and Irvine, 1934). Aminonitrile compounds present in these beans are said to cause the above symptoms plus cerebellar effects caused by bis (B - cyancethy) - amine. Some beans also contain abnormally high levels of selenium and manganese which may be toxic. In soy beans there are inhibiotory, toxic and stimulatory factors. Soybean extract was found to promote growth and reproduction in rats (Markley et. al., 1950) and in chickens (Offiong, 1984), after heating while an antioxygenic factor was found to prevent fats and oils from deterioration (Hildith and Paul, 1939). Also, an allergenic substance (Wilgus et. al., 1941), and an antithyrotoxic active substance (O'Dell et. al., 1955) have been reported. A blood coagulant and an anticoagulant were reportedly present but of utmost improtance is the anti-trypsin factor which can be destroyed by moderate heat. And when this trypsin inhibitor is removed, the nutritive value of soybean meal is greatly improved (Cravens and Sipos, 1958). Cultural normal practice of soaking beans to remove the testa and throwing away steeping water effectively removes most of the unwanted toxic elements. Seed

germination and fermentation also removes toxic principles.

Also, some soybean proteins adversely affect feed utilisation. Such proteins are easily destroy by heat while the nutritionally valuable proteins are more heat resistant. Such proteins contain toxic amino acids such as canavalin, mimosine, and albizzine. Toxic principles in other feedstuffs include gossypol in cottonseed, sinapine, tannins and phytates, glycosinolates and erucic acid in rapeseed and mustard seeds, aflatoxin from fungal contamination in groundnuts, theobromine in cocoa, sesamin and sesamolin in sesame seeds (beniseed) Chopral et. al., 1965). Consumption of sesamin and sesamolin in large amounts cause colic, tremor, dysponea, distention, cough and depression. In addition to toxicity, these anti-nutritional factors make the feedstuffs unpalatable and unacceptable to livestock. Therefore, their removal greatly improves the nutritive value of the feeds.

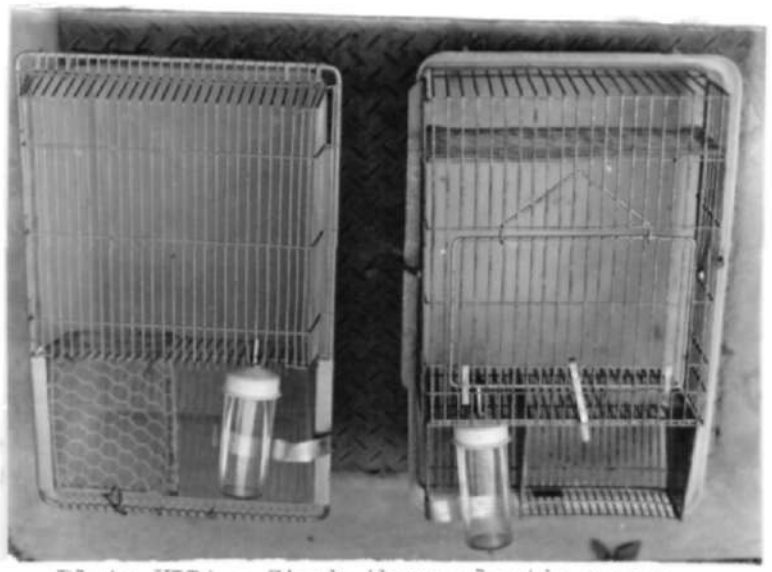


Plate VIIA = Stock thermoplastic cages
without any reconstruction



Plate VIIB = Converted experimental cages



Plate VIIC = Converted cages without
covers to show modifications

both faeces and urine to fall through easily. The faeces and spilled food were caught by another screen of smaller meshes which was placed below the screen supporting the rats. The smaller mesh screen permitted the urine to drain through onto a funnel-shaped pan which directed it into a plastic container below. The food trough was placed inside the cage to enable the young animals easy access to it. Water was supplied in standard water bottles located outside the cages but with their tubes projecting into the cages.

2.1.3. Animals:

Young growing weanling albino rats of the wister strain, 21-23 days old, were placed on the Pfizer (Prizer Mills Limited, Lagos) mice cube stock diet for a period of 7 days so that at the beginning of each experimental period, the rats were 28-30 days of age. These rats were obtained from the National Institute of Trypanosomaisis Research, Vom, near Jos, Plateau State of Nigeria.

The sexes of the rats were distinquished by the use of external characteristic according to Jackson (1912). The male was characterised by a large genital papilla and a greater distance between the anus and the genital papilla while the female has a relatively smaller genital papilla and a shorter distance between the anus and the genital papilla.

2.2. Methods

2.2.1. Fermentation of seeds of Parkia and Tamarindus

The African locust bean and the Indian tamarind seeds were fermented according to normal local processing procedure. This consisted of boiling and cooking the seeds for 6 hours until the testa could be removed by rubbing between two fingers (Fetuga, 1974, Simons, 1976 and Eka, 1980). The seeds were then placed in a mortar and gently pounded with the pestle to separate the testa from the seed nuts. The testa was strained from the seed nuts by washing in tap water. The clean seed nuts were then placed in an earthenware pot and cooked for another 30 minutes, after which they were stacked in plastic trays. The trays and contents were covered and placed in a warm cupboard in the laboratory and left for 3 days to enable the seed nuts to ferment. The fermented seed nuts were sun-dried, then oven dried to constant weight, after which they were ground into powder and stored in screw-capped bottles.

2.2.2. Preparation of Starch from Corn, Cassava and Cocoyam

Peeled cassava root tubers and cocoyam corms were sliced, washed and ground into paste using a waring blender (Model 11BL50) with stainless steel blades. The corn was soaked for 24 hours and similarly ground in the Mill. The paste of each foodstuff was thoroughly mixed with water in a large plastic bowl and then filtered. The suspension obtained was left to stand overnight. By the next morning, the

starch had settled at the bottom of the container. The water was then decanted and the starch was poured into a new jute bag. The bags was tied at the mouth with a rope and placed on a bed of sticks. Heavy stones were placed on top of the bag as weights in order to facilitate the removal of excess water from the starch. At the end of 24 hours, the starch was removed from the jute bag, sun-dried and stored in screw-capped plastic bottles. Before diet preparation, the starch was autoclaved at 15 lb/sq in and 120 ^{o}C for 30 minutes, using a Baird and Tatlock Model 32E autoclave.

2.2.3. CHEMICAL ANALYSIS

Moisture, dry matter, ash and organic matter determinations of all samples of foodstuffs were done by the oven-dry and Muffle Furnace methods, while crude lipid (fat) content was done by the Soxhlet method according to Osoborne et. al., (1978). Nitrogen and crude protein were determined according to the micro kjeldal method reported by Bradstreet (1957), while crude fibre was done by the modified Weende method (AOAC, 1970). The detailed description of the determinations are found in Appendix 1.

2.2.3.1. Amino Acid Determination

Amino acid determination was done by first hydrolysing each sample and then loading the prepared hydrolysate into the Technicon TSM-1 Amino acid Analyser at the National Animal Production Research Institute (NAPRI) in Shika (ACAC, 1970).

2.2.3.1.1. *Open-flask Acid Hydrolysis of Samples*

400-500mg of oven dried ground and defatted sample was carefully weighed into a 250ml round bottom flask and some anti-bumping granules were added. 170mls of 6N Hydrochloric acid was added and the mixture refluxed for 24 hours on a heating mantle. The hydrolysate was allowed to cool and made up to 250mls in a graduated flask at room temperature. This solution was filtered through Whatman No40 filter paper. 25mls aliquot of the filtrate was then evaporated on a rotary evaporator, to dryness at 39°C. Two 2ml portions of deionised water were added, evaporated to dryness each time and the residue was picked up in 25mls buffer pH2.

2.2.3.1.2. Estimation of Amino Acids

1.0ml of the final solution of the hydrolysate was loaded on to the Technicon TSM-1 Amino acid analyser for the determination of basic, neutral and acidic amino acids except trypophan which were completely destroyed during the acid hydrolysis and cystine which was partially destroyed.

2.2.3.1.3. Chemical Score (C.S.) or Protein Score (P.S.)

Chemical score was calculated according to Block and Mitchell (1946) as follows: The content of each of the essential amino acid of a protein expressed as a percentage of a standard; the lowest percentage being taken as the chemical score. The standard or reference protein used in this case was egg protein (WHO/FAO, 1973). Thus:

$$C.S. = \frac{\text{mg of essential amino acid of test protein}}{\text{mg of essential amino acid in egg protein}}$$

2.2.3.1.4. Essential amino Acid Index (EAA1)

The essential amino acid index was calculated as the geometric mean of the ratios of the essential amino acids in a protein to those of a standard or reference (usually egg protein) (Oser, 1951). The geometric mean of the ratios as calculated in (section 2.2.3.1.3). above was taken as the EAA1.

2.2.3.1.5. Essential to Non-Essential Amino Acid (E:N)

The essential to non-essential amino acid is the grammes of essential amino acids per gramme of non-essential amino acids in the food protein, in terms of nitrogen. The calculation was done according to Swendseid et. al., (1963).

2.2.3.1.6. Essential Amino Acid Per Gramme Total Nitrogen (E:T)

The essential amino acid per gramme of total Nitrogen was calculated according to FAO/WHO expert group on protein requirement (1968) as follows: E:T = grammes of essential amino acids per gramme total nitrogen.

2.2.3.2. Determination of Mineral Elements

One hundred milligrammes of the previously ashed samples were digested in a 100ml Volumetric flask containing 10mls of 36% hydrochloric acid and then made up to mark with deionised water.

Blank and duplicate were prepared in a similar way. The solution was then used to determine each mineral element in the samples.

The standard Flame Emission photometer was used to determine Sodium, Calcium, Potassium, and Magnesium while Iron, Zinc, cooper and Manganese were determined with a Perkin-Elemer Model 290B Atomic Absorption Spectrophotometer. Phosophorus was determined by using the Vanadomolybdate Colorimetric (Yellow) method and the Spectronic 20 (AOAC, 1970).

2.2.3.3. Determination of Nitrogen-Free Extract (NFE)

The nitrogen-free extract was derived according to Crampton and Harris (1968) as follows:

NFE = 100 -

(% moisture +% crude protein +% crude fat +% crude fibre +% Ash).

2.2.3.4. Determination of Carbohydrates

Total carbohydrates was calculated by the difference method as described by Schneider and Flat (1975) as follows:

Carbohydrates percent = (percent crude fibre + NFE).

2.2.3.5. Determination of Calorific Value

Conversion factors (Atwater factors) as described by AOAC (1970) were used to derive calorific values as follows:

(a) Carbohydrates percent was multiplied by 4.0 Kcals/100g

(b) Lipid (fat) percent was multiplied by 9.0 Kcals/100g

(c) Protein percent was multiplied by 4.0 Kcals/100g

All three (a,b,c,) were then added together to give the claorific value.

2.2.3.6. Determination of Body Water of Experimental Rats

The body water was determined as follows:

Body water percent = weight of rat before oven-drying (W1) - weight of rat after oven-drying (W2) divided by weight of rat before oven-drying, multiplied by 100, i.e.

$$\frac{W1 - W2}{W1} \times 100$$

2.2.3.7. Determination of Body Nitrogen of Rat Carcasses

After determination of body water, each rat carcass together with its intestinal contents and the pieces of blood stained nitrogen-free filter paper were digested according to Rippon (1959) with slight modifications (Fetuga 1974, Umoh and Oke, 1974) in one-litre volumetric flask. 100mls concentrated sulphuric was poured over the carcass and allowed to soak for 10 minutes. 100mls of distilled water was then cautiously added from a burrette. The dissolution of the carcass started immediately the water was added and there was no need to autoclave the digest. The digest was then allowed to cool gradually with occasional swirling. Twenty four-hours later, 25ml portions of the cooled dark-red solution was taken in duplicate for carcass nitrogen determination as described in Appendix 1.

2.2.4. BIOLOGICAL EVALUATION STUDIES

The biological evaluation studies consisted of two separate experiments as shown by the experimental designs in Table 2.1. & 2.4.

2.2.4.1. EXPERIMENT 1

The objectives of this experiment were to biologically evaluate the protein quality of the seeds of Parkia clappertoniana and Tamarindus indica using casein as the reference protein and to determine the performance of rats on cassava and cocoyam starches in place of corn starch.

12 different diest were compounded as indicated in Table 2.1, using fermented Parkia clappertoniana and Tamarindus indica seeds. Casein was used as the standard protein while corn, cocoyam and cassava starches were the sources of energy. The protein sources were in-corporated at the 10 percent protein level at the expense of the starches. The 10 percent protein levels were calculated as shown in appendix 2.

The composition of both the mineral and vitamin premixes are tabulated on Table 2.2. The general out-lay of the experiment is shown in Table 2.3.

A total of 72 male weanling albino rats were used. They were weaned between 21-23 days old and weighed. Then, they were fed

Table 2.1. Diet Composition for Experiment 1 in g/kg

Ingredients	Diet No.[1] 1,5 & 9	2,6 & 10	3,7 & 11	4,8 & 12
Starch	650	534.2	432.61	138.23
Casein	-	115.8	-	-
Fermented Parkia seed nuts	-	-	217.39	-
Fermented Tamerindus seed nuts	-	-	-	511.77
Common ingredients[2]	350	350	350	350

1. Diets 1 to 4 have corn starch; 5 to 8 cassava starch and 9 to 12, cocoyam starch.
2. Common ingredients consisted of the following (in grammes), sucrose, 120; oil, 80; roughage, 50; non-protein vitamin premix, 20 and non-protein mineral premix, 80.

Table 2.2. Composition of Non-protein Mineral and Vitamin Premixes Per Kilogramme diet

Nutrients	Composition
Mineral premix	
Calcium	0.6%
Phosphorus	0.7%
Sodium chloride	0.5%
Manganese	25ppm
Copper	7ppm
Cobalt	0.4ppm
Iron	30ppm
Iodine	1.3ppm
Magnesium	102ppm
Vitamin premix	
Vitamin A (retinol)	8000 l.u.
Vitamin D_3 (calciferol)	1000 l.u.
Vitamin E (-tocopherol) acetate	60 l.u.
Vitamin K (menadione)	10mg
Thiamine hydrochloride (B_1)	4mg
Riboflavin (B_2)	8mg
Pantothenic acid	12mg
Nicotinic acid (*niacin*)	50mg
Folic acid (folacin)	10mg
Pyridoxine hydrochloride (B_6)	6mg
Choline chloride	200mg
Cobalamin (B_{12})	12mg

Supplied by Labsure, RHM
Agriculture (Sough) Ltd. Poole, Dorset
BH 15 1HL (Registered Office), England

Table 2.3. The Design for Experiment 1

CS	CA	CO
CSCN	CACN	COCN
CSPA	CAPA	COPA
CSTA	CATA	COTA

Key

1. CS = Corn Starch diet only
2. CSCN = Corn Starch + Casein diet
3. CSPA = Corn Starch + Parkia diet
4. CSTA = Corn Starch + Tamarindus diet
5. CA = Cassava Starch diet only
6. CACN = Cassava Starch + Casein diet
7. CAPA = Cassava Starch + Parkia diet
8. CATA = Cassava Starch + Tamarindus diet
9. CO = Cocoyam Starch diet only
10. COCN = Cocoyam Starch + Casein diet
11. COPA = Cocoyam Starch + Parkia diet
12. COTA = Cocoyam Starch + Tamarindus diet.

Pfizer mice cube stock diet for a period of one week until they were 28-30 days of age. Each rat was then housed individually in the modified plastic metabolic cages (plate VIIA, section 2.1.2. above) and fed the experimental diets for 10 days. The first 3 days was regarded as an acclimatization period during which no records of food consumption or collection of faeces were kept. A small quantity of water was mixed with weighed amount of the diet which was then made into a thick paste in order to minimise spillage and scattering by the animals. Both food and water were supplied ad libitum.

Collection of faeces was made during the last 7 days of the experiment. Faeces were separated from spilled food and particles of hair were also picked and discarded. The faeces of each rat were pooled, weighed and oven dried to a constant weight. The faeces were cooled in a dessicator ground into powder and stored in screw - capped plastic bottles, ready for faecal nitrogen determination.

Daily weight changes and food consumption per rat were also measured and recorded.

At the end of the experimental period, all the rats were killed with chloroform and incisions made into the skull, thorax and abdomen. The carcasses, including intestinal contents and small pieces of nitrogen-free filter paper used to mop up spilled blood during dissection were dried in the oven to constant weight. Body water and carcass nitrogen were determined as described in Appendix 1. . . .

The biological indices derived from measured parameters according to NAS/NRC (1963) include:

a) Weight gain or loss by each rat: Weight gain/loss = weight of rat after experiment - weight of rat before experiment.

b) Feed conversion ratio (FCR):

$$FCR = \frac{\text{Total feed intake}}{\text{weight gain/loss.}}$$

c) Protein efficiency ratio (PER):

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

d) Apparent Digestibility (AD):

$$AD = \frac{\text{Intake nitrogen - faecal nitrogen}}{\text{Intake nitrogen}} \times \frac{100}{1}$$

e) Biological value (BV):

$$BV = \frac{\text{Retained nitrogen}}{\text{absorbed nitrogen}}$$

f) Net protein utilisation (NPU):

$$NPU = \frac{\text{Retained nitrogen}}{\text{nitrogen intake.}}$$

These determined biological indices for each rat, are contained in Appendix 3.

2.2.4.2. EXPERIMENT 2

This experiment was designed to assess the effect of supplementing the proteins of the seeds of Parkia clappertoniana and Tamarindus indica with L-methionine using corn, cassava and cocoyam starches.

One hundred and twenty-six weanling male albino rats, similar in age and sex as described in Experiment 1, were used. The experimental procedure was also similar except that a total of 21 diets were used after supplementation with L-methionine (Table 2.4). The lay out and dietary treatment in Experiment 2 are shown in Table 2.5.

The measured biological indices were subjected to the analysis of variance and comparison of treatment means were done by the least significant differences (Campbell, 1981). The determined biological indices for each rat are given in Appendix 4.

Table 2.4: Diet Composition of Experiment 2 in g/kg

Ingredients	Diet No.[1] 1,8 & 15	2,9 & 16	3,10 & 17	4,11 & 18	5,12 & 19	6,13 & 20	7,14 & 21
Starch	650	534.2	5531.4	432.61	429.81	138.23	135.43
Casein	-	115.8	115.8	-	-	-	-
Fermented Parkia seed nuts	-	-	-	217.39	217.39	-	-
Fermented Tamarindus seed nuts	-	-	-	-	-	511.77	511.77
Common ingredients[2]	350	350	350	350	350	350	350

1. Diets 1 to 7 have corn starch, 8 - 14 cassava starch and 15 to 21, cocoyam starch.

2. Common ingredients consisted of the following (in grammes); sucrose, 120; oil, 80; roughage, 50; non-protein vitamin premix, 20 and non-protein mineral premix, 80.

Table 2.5. The Design for Experiment 2

CS	CA	CO
CSCN	CACN	COCN
CSCNM	CACNM	COCNM
CSPA	CAPA	COPA
CSPAM	CAPAM	COPAM
CSTA	CATA	COTA
CSTAM	CATAM	COTAM

Key

1. CS = Corn Starch diet only
2. CSCN = Corn Starch + Casein diet
3. CSCNM = Corn Starch + Casein + Methionine diet
4. CSPA = Corn Starch + *Parkia* diet
5. CSPAM = Corn Starch + *Parkia* + Methionine diet
6. CSTA = Corn Starch + *Tamarindus* diet
7. CSTAM = Corn Starch + *Tamarindus* + Methionine diet
8. CA = Cassava Starch diet only
9. CACN = Cassava Starch + Casein diet
10. CACNM = Cassava Starch + Casein + Methionine diet
11. CAPA = Cassava Starch + *Parkia* diet
12. CAPAM = Cassava Starch + *Parkia* + Methionine diet
13. CATA = Cassava Starch + *Tamarindus* diet
14. CATAM = Cassava Starch + *Tamarindus* + Methionine diet
15. CO = Cocoyam Starch diet only
16. COCN = Cocoyam Starch + Casein diet
17. COCNM = Cocoyam Starch + Casein + Methionine diet
18. COPA = Cocoyam Starch + *Parkia* diet
19. COPAM = Cocoyam Starch + *Parkia* + Methionine diet
20. COTA = Cocoyam Starch + *Tamarindus* diet
21. COTAM = Cocoyam Starch + *Tamarindus* + Methionine diet.

CHAPTER THREE

3. RESULTS

3.1. CHEMICAL ANALYSIS

Results of the gross chemical analysis are presented in Tables 3.1 to 3.5.

3.1.1. *Cassava and Cocoyam*

Table 3.1. refers to the proximate and mineral compositions of cassava root-tubers and cocoyam corms.

Both cassava and cocoyam contain high amounts of moisture, organic matter, nitrogen - free - extract, total carbohydrates and calories. The peeled portions were highest in organic matter, nitrogen - free - extract, total carbohydrates and calories, followed by the unpeeled while the peels had the lowest values. The moisture and crude fibre contents for both tubers were highest in their peels followed by the unpeeled and the peeled portions, respectively. Values for cassava were generally higher than corresponding values for cocoyam except for moisture content which was higher in cocoyam.

Crude protein, lipid and ash contents were low for both cassava and cocoyam. The peels contained highest amounts of ash and minerals than either the unpeeled and peeled portions. The results also showed that cocoyam contained more protein, ash and

Table 3.1. Proximate and Mineral Compositions of Sweet Cassava root tubers and Cocoyam Corms (% DM basis)

Nutrient	Whole Cassava Unpeeled	Whole Cocoyam Unpeeled	Peeled Cassava (Tissue only)	Peeled Cocoyam (Tissue only)	Cassava Peels only	Cocoyam Peels only	Corn (TZB)
Moisture Content	56.75	75.25	55.90	67.00	65.20	76.25	6.99
Dry Matter	43.25	24.75	44.10	33.00	24.80	23.75	93.11
Ash	2.69	4.25	2.30	3.43	5.75	5.69	1.68
Organic Matter	97.31	95.75	97.70	96.57	94.25	94.31	94.16
Crude Protein	5.25	7.93	3.33	6.70	7.22	7.19	12.08
Crude Lipid	0.73	0.55	0.53	0.36	1.40	0.69	3.15
Crude Fibre	3.96	3.79	2.14	2.18	10.06	7.30	2.61
Nitrogen-free-Extract	87.37	83.48	91.70	87.33	75.75	79.13	82.08
Carbohydrate by difference	91.33	87.27	93.84	89.51	85.63	86.43	82.16
Calories (Cal/100g)	377.05	370.59	384.49	379.36	343.76	351.49	360.85
Minerals:							
Sodium	0.05	0.06	0.07	0.06	0.09	0.07	0.002
Potassium	0.43	0.95	0.88	0.68	1.50	1.20	0.26
Calcium	0.10	0.07	0.56	0.05	0.63	0.17	0.01
Magnesium	0.09	0.13	0.09	0.12	0.13	0.20	0.09
Phosphorus	0.02	0.15	0.03	0.12	0.05	0.15	0.18
Zinc (ppm)	52.00	80.00	20.00	65.00	115.00	115.00	32.50
Iron (ppm)	80.00	200.00	20.00	60.00	320.00	300.00	25.00

In Tables 3.1, 3.2, 3.3 and 3.4, the Figures indicate average values for two samples since the two readings were very close (see Appendix 5A-5D).

minerals than the cassava which had higher amounts of crude lipid and calories.

On the other hand when the compositions of the tuber crops were compared with those of the corn, it was found that corn contained higher dry matter, crude lipid, crude protein and phosphorus. Corn had lower amounts of moisture, crude fibre and mineral elements.

3.1.2. Parkia and Tamarindus seeds

Table 3.2. shows the proximate and mineral compositions of the African locus bean (Parkia) tamarind (Tamarindus) seeds.

The results showed that both seeds were relatively high in crude protein, lipid and calories. Generally, the crude protein, lipid and caloric contents of Parkia were higher than those of the Tamarindus seeds. The fermented seed nuts tended to be higher than the unfermented in their contents of organic matter, crude protein and calories. In the Tamarindus, the seed nuts had the highest crude lipid content. The nitrogen-free - extract tended to be higher in the fermented seed nuts than in the unfermented Tamarindus seed nuts, followed by the whole seeds and the seed testa. In Parkia, the results indicated that the nitrogen-free-

Table 3.2. Proximate and Mineral Compositions of Parkia and Tamarindus seeds (in %DM basis, Average values)

Nutrient	Parkia Whole seeds	Tamarindus whole seeds	Parkia seed nuts (kernel)	Tamarindus seed nuts (kernels)	Parkia Lab. Fermented	Parkia market Fermented	Tamarindus Fermented seed nuts	Parkia seed testa (soaked)	Tamarindus seed testa (boiled)
Moisture Content	7.35	10.98	12.50	25.65	6.25	12.50	34.80	16.75	36.80
Dry Matter	92.65	89.02	87.50	74.35	93.75	87.50	65.20	83.25	63.20
Ash	4.33	2.35	2.11	1.62	1.74	5.11	1.46	3.37	2.25
Organic Matter	95.67	97.65	97.89	98.38	98.26	94.89	98.54	96.63	97.75
Crude Protein	28.20	16.06	45.36	19.20	46.00	33.44	19.54	9.36	10.20
Crude Lipid	15.76	3.26	27.74	3.54	30.32	27.29	2.32	1.42	0.38
Crude Fibre	14.21	3.18	4.69	2.16	7.25	8.85	2.47	36.40	24.71
Nitrogen-free extract	37.50	75.15	20.10	73.48	14.69	25.31	74.21	22.45	62.46
Carbohydrate by difference	51.71	78.33	24.79	75.64	21.94	34.16	76.68	58.85	87.17
Calories (Cal./100g)	404.64	374.38	511.58	402.58	515.64	344.04	395.88	140.02	294.06
Minerals									
Sodium	0.01	0.004	0.02	0.02	0.02	0.02	0.02	0.05	0.02
Potessium	1.00	0.20	0.18	0.09	0.22	0.50	0.12	0.56	0.06
Calcium	0.22	0.10	0.11	0.20	0.15	0.16	0.25	0.07	0.06
Magnesium	0.34	0.10	0.19	0.13	0.18	0.21	0.14	0.30	0.30
Phosphorus	0.26	0.21	0.30	0.23	0.39	0.39	0.27	0.01	0.01
Zinc (ppm)	80.00	87.50	95.65	39.95	105.00	70.00	47.50	32.26	16.62
Iron (ppm)	75.00	75.00	100.07	101.55	200.00	575.00	150.00	55.65	97.55

extract was highest in the whole seeds followed by the testa, the unfermented and fermented seed nuts. The market fermented seed nuts had more nitrogen-free-extract than the laboratory fermented seed nuts and its value was next to that of the whole seeds.

The moisture, crude fibre and total carbohydrate contents were highest in the seed testa, followed by the whole seeds, the fermented seed nuts and the unfermented seed nuts. The crude fibre content was highest in the seed testa, followed by the whole seeds, the fermented seed nuts and the unfermented seed nuts. Corresponding values for Parkia were higher than those of the Tamarindus.

The ash content of Parkia seeds was higher than that of the Tamarindus seeds. All parts of both seeds contained fair amounts of minerals but the mineral contents of Parkia were generally higher than those of the Tamarindus except for calcium which was higher in the Tamarindus whole seeds than in Parkia whole seeds. Also, iron contents of the Tamarindus seed nuts and testa were higher than in Parkia seed nuts and testa. Fermentation generally tended to increase mineral contents except in the case of sodium which remained the same and magnesium which was slightly lower in the case of the laboratory fermented Parkia seed nuts.

The Parkia seed nuts contained more minerals, except, potassium, calcium and magnesium, than the whole seeds, while the

seed testa contained more sodium and potassium than the whole seeds and in addition, more magnesium than the seed nuts. The Tamarindus seed nuts contained more minerals than the whole seeds, except, in the case of potassium and zinc, while the seed testa had higher amounts of sodium, magnesium and iron than the whole seeds. But the seed testa was higher than the seed nuts in its contents of only magnesium.

3.1.3. Amino Acid Composition

The amino acid contents of the cassava and cocoyam are presented in Table 3.3 while those of Parkia and Tamarindus seeds are shown in Table 3.4.

The results consistently showed that the cocoyam portions had higher amounts of amino acids than corresponding values for cassava except possibly in arginine (Table 3.3).

For cassava, the peels tended to contain the highest amounts of virtually all the amino acids determined, followed by the unpeeled and the peeled portions.

In the cocoyam, the unpeeled followed by the peeled and then the peels contained the highest amounts of the lysine, arginine, aspartic acid, threonine, serine, leucine, phenylalanine and valine. Then, the unpeeled cocoyam, followed by the peels and the peeled contained highest amounts of histidine, glutamic acid and glycine.

Table 3.3. Amino Acid Composition of Sweet Cassava Root Tubers and Cocoyam Corms (% DM, Fat-Free-Basis, Average Values)

Amino Acid	Whole Cassava unpeeled	Whole Cocoyam unpeeled	Peeled Cassava (Tissue only	Peeled Cocoyam (Tissue only)	Cassava Peels only	Cocoyam Peels only	Corn (TZB)
Lysine	0.19	0.62	0.14	0.54	0.35	0.49	0.45
Histidine	0.10	0.34	0.07	0.30	0.20	0.31	0.59
Arginine	1.11	1.03	0.50	0.87	1.91	0.72	0.73
Aspartic Acid	0.23	1.40	0.16	1.24	0.46	1.23	1.61
Threonine	0.09	0.49	0.06	0.46	0.16	0.44	0.76
Serine	0.12	0.62	0.08	0.59	0.22	0.57	0.97
Glutamic Acid	0.64	1.12	0.46	0.99	0.97	1.04	4.12
Proline	0.09	0.36	0.05	0.35	0.16	0.36	1.86
Glycine	0.10	0.57	0.08	0.52	0.18	0.53	0.74
Alanine	0.15	0.49	0.13	0.48	0.25	0.48	1.89
Cystine	nd	0.21	nd	0.20	nd	0.23	0.27
Valine	0.11	0.53	0.08	0.52	0.20	0.50	1.12
Methionine	0.05	0.10	0.03	0.11	0.06	0.10	0.34
Isoleucine	0.11	0.38	0.06	0.39	0.18	0.35	1.00
Leucine	0.16	0.87	0.10	0.85	0.27	0.81	2.75
Tyrosine	0.10	0.46	0.06	0.43	0.19	0.43	0.90
Phenylalanine	0.10	0.52	0.06	0.49	0.17	0.48	1.23

nd = not detectable.

The content of proline was the same in both the unpeeled and peels of the cocoyam. Alanine was highest in the unpeeled cocoyam while its contents in the peeled and peels were the same. The cystine content of the peels was highest followed by the unpeeled and then the peeled. Methionine was highest in the peeled portion while its contents were the same in both the unpeeled and the peels of cocoyam. The isoleucine content of the peeled portion was higher than in the unpeeled, followed by the peels.

When the amino acid contents of the corn were compared with those of the cassava and cocoyam, the results showed that those of the cassava were lower in all cases except for arginine where all the cassava portions had higher amounts than the corn. For cocoyam, all the parts, contained more lysine and arginine except in the peels where arginine content was lower than in corn. Otherwise, corn had higher amounts of all the remaining amino acids than cocoyam. The amino acid contents of Parkia were generally higher than those of the Tamarindus except for the whole seeds and seed testa where corresponding glycine values for the Tamarind were higher (Table 3.4).

The seed nuts generally recorded highest amounts of amino acids than the whole seeds and seed testa. Fermentation seemed to increase all the amino acid contents of Parkia seed nuts although, values for cystine and methionine were still lower than corresponding values of the whole seeds. In the Tamarind, fermentation tended to increase only lysine, histidine, alanine, cystine, methionine,

Table 3.4. Amino Acid Composition of Parkia and Tamarindus Seeds (% DM, Fat-Free-Basis, Average values)

Amino Acid	Parkia whole seeds	Tamarindus whole seeds	Parkia seed nuts (kernels)	Tamarindus seed nuts (kernels)	Parkia fermented seed nuts	Parkia market fermented	Tamarindus fermented seed nuts	Parkia seed testa	Tamarindus seed testa	Casein
Lysine	2.58	1.35	4.04	1.87	4.07	3.15	1.96	0.80	0.34	0.34
Histidine	1.16	0.71	1.93	0.72	1.95	1.40	0.74	0.42	0.93	2.64
Arginine	2.04	1.51	3.27	1.48	3.11	1.84	1.41	0.66	0.53	3.33
Aspartic Acid	3.31	1.95	4.54	2.75	4.53	3.40	2.70	0.95	0.79	6.74
Threonine	1.26	0.60	1.88	0.82	1.74	1.18	0.78	0.42	0.22	4.00
Serine	1.78	1.06	2.67	1.35	2.46	1.40	1.32	0.58	0.55	5.25
Glutamic Acid	5.14	2.94	7.36	4.11	7.42	6.07	4.01	1.48	1.08	20.62
Proline	1.63	0.64	2.27	0.93	2.14	1.39	0.92	0.43	1.19	10.07
Glycine	1.48	1.54	2.20	1.22	2.15	1.61	1.19	0.83	1.52	1.74
Alanine	1.72	0.79	2.58	1.04	2.54	1.78	1.08	0.60	0.33	2.88
Cystine	2.24	0.39	1.05	0.42	0.87	0.63	0.44	0.14	0.12	0.33
Valine	1.51	0.73	2.58	1.10	2.45	1.90	1.09	0.50	0.20	6.21
Methionine	1.00	1.19	0.28	0.25	0.43	0.34	0.28	0.10	0.05	2.60
Isoleucine	1.45	0.84	2.27	1.18	2.25	1.72	1.24	0.42	0.21	4.81
Leucine	2.52	1.35	3.76	1.85	3.71	2.81	1.94	0.70	0.34	8.66
Tyrosine	1.08	1.01	2.04	1.17	1.89	1.74	1.14	0.38	0.84	5.33
Phenylalanine	1.66	0.85	2.60	1.24	2.55	1.92	1.18	0.43	0.25	4.92

leucine and isoleucine while majority of the amino acids were lower than in the unfermented seed nuts.

When the amino acid contents of the seeds were compared with those of casein, it was found that they were very much lower than those of casein except for cystine which was higher in both seeds. However, the seed testa had lower amounts of cystine than in casein.

The essential to non-essential (E:N) and the essential to total nitrogen (E:T) ratios, the essential amino acid index (EAAI) and the chemical or protein score (CS/PS) values (Table 3.5), for the Parkia, were higher than those of the Tamarindus except in the case of the fermented seed nuts where the EAAI and CS/PS were lower in Parkia than in Tamarindus.

Cassava (Manihot esculenta) had a higher E:N than the egg, which is the standard, and the cocoyam (Colocasia esculenta). However, cocoyam had higher EAAI and CS/PS values than cassava except for the peeled tissues where the CS/PS values were similar.

Table 3.5. E:N. and E:T. Ratios, EAAI and C.S./P.S. of Parkia Tamarindus Cassava and Cocoyam

	Foodstuffs	E:N[a]	E:T[b]	EAAI[c]	C.S./P.S[d].
1	Parkia, whole seeds	0.83	45.52	84.26	63
2	Parkia, uncooked seed nuts	1.11	52.69	80.95	18
3	Parkia, cooked and fermented seed nuts	0.93	48.12	78.00	25
4	Parkia, market fermented seed nuts	0.90	47.40	72.93	25
5	Parkia, seed testa	0.82	45.03	67.32	24
6	Tamarindus, whole seeds	0.79	44.03	71.93	28
7	Tamarindus, uncooked seed nuts	0.81	44.66	75.93	29
8	Tamarindus, cooked and fermented seed nuts	0.83	45.43	78.11	34
9	Tamarindus, seed testa	0.56	35.74	36.19	12
10	Whole hen's egg	1.01	50.50	100.00	100.00
11	Manihot esculenta, whole, unpeeled root tuber	1.40	58.27	33.49	18
12	Manihot esculenta, peels only	1.44	58.99	43.53	19
13	Manihot esculenta, peeled tissue only	1.11	52.69	53.11	31
14	Colocasia esculenta, whole, unpeeled corms	0.93	48.26	72.35	26
15	Colocasia esculenta, peels only	0.84	46.40	74.40	26
16	Colocasia esculenta, peeled tissue only	0.94	48.56	77.43	31

a = Essential to non-essential amino acid ratio
b = Essential amino acid to total nitrogen ratio
c = Essential amino acid index
d = Chemical or Protein scores

3.2. BIOLOGICAL EVALUATION STUDIES

3.2.1. EXPERIMENT I

Results of experiment I are shown in Table 3.6. The analysis of variance is shown in table 3.7.

It was observed that rats on the Parkia diet had significantly ($P<0.01$) higher protein intake when corn and cocoyam starches were used than those on the Tamarindus diet, but the reverse was the case when cassava starch was used as carbohydrate source. These results also showed that rats on the casein diet had significantly ($P<0.01$) higher protein intake when cassava and cocoyam starches were employed than when corn starch was used as the carbohydrate source. All rats on both the Parkia and Tamarindus diets lost weight significantly ($P<0.001$) irrespective of whether cassava or cocoyam starch was used while those on the corn starch - Parkia gained weight significantly ($P<0.001$) more than any other non-casein diet. The rats on the standard casein diet significantly ($P<0.001$) gained more weight than those on the Parkia and Tamarindus although there was no significant difference between the cassava and cocoyam-casein deits.

The caroass nitrogen contents of rats were significantly ($P<0.001$) higher for casein and Parkia than Tamarindus diets, irrespective of the type of carbohydrate source but significantly ($P<0.05$) higher for casein than Parkia when corn and cocoyam starches were used and more signficantly ($P<0.001$) higher for

Table 3.6. EXPERIMENT 1: Measured Biological Indices for Rats Fed Two Nigerian Seed Protèins Using three types of Starch (Means from pooled results in Appendix 1)

S/No.	Diets	Weight gain (g)	Total feed intake (g)	Protein intake (g)	Carcass water content (mg/g)	Carcass Nitrogen content (g)	Carcass Nitrogen content (mg/g) live weight	AD	FCR	PER	BV	NPU
1	Corn Starch + Parkia	1.30	43.3	4.33	692.40	0.95	25.75	78.33	33.02	0.30	0.38	0.28
2	Corn Starch + Tamarindus	-4.40	22.3	2.23	720.80	0.71	27.20	78.83	-6.70	-2.11	0.29	0.23
3	Corn Starch + Casein	5.95	24.7	2.47	708.40	0.87	28.71	80.03	5.80	2.23	0.52	0.41
4	Cassava Starch + Parkia	-4.80	26.9	2.69	695.90	0.94	28.48	75.59	-33.02	-1.87	0.30	0.21
5	Cassave Starch + Tamarindus	-4.94	55.7	5.57	641.20	0.77	24.68	79.08	-11.28	0.90	0.31	0.24
6	Cassava Starch + Casein	4.90	43.7	4.37	694.90	1.26	30.22	81.50	13.49	1.56	0.49	0.40
7	Cocoyam Starch + Parkia	5.60	58.5	5.85	659.20	0.83	26.95	75.78	-16.09	-2.43	0.26	0.20
8	Cocoyam Starch + Tamarindus	-4.90	34.8	3.48	704.90	0.74	21.08	73.43	-13.35	-1.53	0.31	0.22
9	Cocoyam Starch + Casein	4.90	58.8	5.88	683.80	0.99	38.37	82.32	12.15	0.85	0.47	0.38
	S.E.D. ±	1.63	17.24	0.98	1.83	0.08	0.08	3.59	5.15	0.88	0.06	0.05

Key: AD = Apparent Digestibility. FCR = Feed Conversion Ration. PER = Protein Efficiency Ratio
BV = Biological Value. NPU = Net Protein Utilisation. S.E.D. = Standard error of Difference of the means

Table 3.7. EXPERIMENT 1: Analysis of Variance for Measured Biological Indices for two Nigerian Seed Proteins Using three Sources of Starch

Sources of Variation (Diets)	(D.F) Degrees of Freedom	Mean Squares: Weight gain	Protein Intake	(AD) Apparent Digestibility	(FCR) Feed Conversion Ratio	(PER) Protein Efficiency Ratio	(BV) Biological Value	(NPU) Net Protein Utilisation	Carcass Nitrogen
Starch	2	97.07^{xxx}	7.43^{NS}	91.68^{NS}	136.96^{NS}	3.60^{NS}	0.01^{NS}	0.01^{NS}	200.15^{xxx}
Protein	3	415.79^{xxx}	67.43^{xxx}	327.14^{xx}	411.76^{x}	59.36^{xxx}	0.20^{xxx}	0.61^{xxx}	94.17^{xxx}
Starch + Protein	6	22.26^{NS}	15.04^{xx}	63.24^{NS}	611.17^{xx}	8.96^{x}	0.01^{NS}	0.003^{NS}	145.49^{xxx}
Residual	60	7.94	2.88	38.68	779.66	2.33	0.01	0.008	7.56

NS = Not Significant. x = $P<0.05$. xx = $P<0.01$ xxx = $P<0.001$

casein than Parkia when cassava starch was the carbohydrate source.

Apparent digestibilities for the Tamarindus diets were slightly, though non-significantly, better than those of the Parkia, when corn and cassava starches were used. For cocoyam starch however, the value for Parkia was significantly ($P<0.01$) higher than Tamarindus. Apparent digestibilities for the casein diets were significantly ($P<0.01$) better than those of Parkia and Tamarindus diets when both cassava and cocoyam starches were used as the main carbohydrate source.

Rats on both the Parkia and Tamarindus diets had significantly lower feed conversion ratio (FCR) ($P<0.05$), protein efficiency ratio (PER) ($P<0.001$), biological value (BV) ($P<0.001$) and net protein utilisation (NPU) ($P<0.001$) than those on casein diets, irrespective of the type of starch utilised. However, there were no significant differences between Parkia and Tamarindus diets when cassava and cocoyam starch were used but when corn starch was used, Parkia had significantly higher values for FCR and PER ($P<0.001$), BV and NPU ($P<0.05$) than Tamarindus.

3.2.2. EXPERIMENT 2

Results of experiment 2 are presented on Table 3.8 and the analysis of variance in Table 3.9.

Methionine addition was found to significantly ($P<0.001$) improve the protein intake of all rats irrespective of the protein or starch sources, except in the case of the cassava starch - Parkia supplemented diet where protein intake was significantly ($P< 0.01$) lower than the unsupplemented cassava starch - Parkia diet. Also, protein intake in the supplemented Tamarindus diets was significantly ($P<0.001$) improved over those of the supplemented Parkia diets. Rats on all the unsupplemented Tamarindus and the cassava starch - Parkia diets significantly ($P<0.001$) lost weight. However, rats on all the unsupplemented casein and the corn starch - Parkia diets significantly ($P<0.001$ and $P< 0.05$ respectively) gained weight. These results were similar to those obtained for experiment 1.

Furthermore, rats on the methionine supplemented casein diets significantly ($P< 0.001$) gained weight, irrespective of the type of starch employed. Also, rats on the supplemented Parkia diets significantly ($P< 0.01$) gained more weight than those on the Tamarindus diet.

The carcass nitrogen contents of all rats except for the cassava starch - Parkia diet were significantly ($P<0.01$) increased with methionine addition and this increase was

Table 3.8. EXPERIMENT 2: The Effect of Feeding Rats with Two Nigerian Proteins Supplemented with DL - Methionine Using three types of Starch

S/No.	Diets	Weight gain (g)	Total Feed intake (g)	Protein intake (g)	Carcass water content (mg/g)	Carcass Nitrogen content (g)	Carcass Nitrogen content (mg/g) live weight	AD	FCR	PER	BV	NPU
1	Corn Starch + Parkia only	0.60	34.7	3.47	701.80	0.83	23.94	78.59	21.80	-0.04	0.34	0.28
2	Corn Starch + Parkia + Methionine (2.5g/kg)	6.03	48.3	4.83	704.90	0.95	19.67	74.83	8.70	1.22	0.40	0.30
3	Corn Starch + Tamarindus only	-4.35	17.8	1.78	651.30	0.78	44.38	75.94	-7.40	-2.47	0.29	0.21
4	Corn Starch + Tamarindus + Methionine (2.5g/kg)	0.77	78.2	7.82	711.50	1.00	12.92	75.11	55.20	0.22	0.32	0.23
5	Corn Starch + Casein only	6.56	31.6	3.16	709.30	0.90	31.47	84.36	5.00	2.07	0.42	0.36
6	Corn Starch + Casein + Methionine (2.5g/kg)	8.97	36.8	3.68	712.00	1.00	27.17	84.25	4.10	2.43	0.56	0.47
7	Cassava Starch + Parkia only	-4.33	65.3	6.53	667.20	1.02	21.59	79.07	-16.60	-1.07	0.48	0.38
8	Cassava Starch + Parkia + Methionine (2.5g/kg)	1.98	47.7	4.77	687.40	0.95	21.69	79.05	25.90	0.55	0.51	0.41
9	Cassava Starch + Tamarindus only	-3.50	21.1	2.10	655.90	0.78	37.14	70.32	-6.80	-1.61	0.27	0.16
10	Cassava Starch + Tamarindus + Methionine (2.5g/kg)	-1.60	49.5	4.95	701.60	0.98	19.76	72.81	-35.70	-0.15	0.41	0.30
11	Cassava Starch + Casein only	3.63	31.7	3.17	695.50	1.03	32.49	83.28	14.50	1.18	0.68	0.57
12	Cassava Starch + Casein + Methionine (2.5g/kg)	15.90	65.3	6.53	717.90	1.41	21.59	82.99	5.00	2.34	0.77	0.64
	* S.E.D. ±	2.30	14.24	1.35	2.44	1.08	1.08	3.29	10.83	0.49	0.08	0.06

AD = Apparent Digestibility. FCR = Feed Coversion Ratio. PER = Protein Efficiency Ratio. BV = Biological Value
NPU = Net Protein Utilisation. *Rats on the cocoyam diets died before any measurements were taken.
S. E. D. = Standard Error of Difference of the Means

Table 3.9. EXPERIMENT 2: Analysis of Variance of Measured Biological for Rats Fed Two Nigerian Seed Proteins Supplemented with DL - Methionine Using three Types of Starch

Sources of Variation (Diets)	(D.F) Degrees of Freedom	Mean Squares: Weight gain	Protein intake	(AD) Apparent Digestibility	(FCR) Feed Conversion Ratio	(PER) Protein Efficiency Ratio	(BV) Biological Value	(NPU) Net Protein Utilisation	Carcass Nitrogen
Starch	1	48.14^{NS}	0.49^{NS}	2.99^{NS}	165.90^{NS}	0.17^{NS}	0.25^{xxx}	0.15^{xxx}	0.19^{NS}
Protein	3	725.61^{xxx}	46.75^{xxx}	256.20^{xx}	2085.90^{xx}	41.03^{xxx}	0.36^{xxx}	0.33^{xxx}	0.25^{xx}
Methionine	1	615.48^{xxx}	93.29^{xxx}	3.60^{NS}	1359.10^{xx}	1.18^{NS}	0.004^{NS}	0.002^{NS}	0.46^{xx}
Starch-Protein	3	62.47	7.37^{xx}	43.41^{NS}	282.00^{NS}	1.76^{NS}	0.09^{x}	0.07^{xx}	0.09^{xx}
Starch-Methionine	1	41.24^{NS}	2.05^{NS}	0.65^{NS}	1157.60^{x}	1.01^{NS}	0.01^{NS}	0.02^{NS}	0.003^{NS}
Protein-Methionine	2	13.75^{NS}	23.65^{xxx}	277.33^{xx}	3562.00^{xxx}	15.49^{xx}	0.13^{xx}	0.10^{xx}	0.08^{x}
Starch-Protein-Methionine	2	54.85^{xxx}	14.53^{xxx}	51.31^{NS}	30.60^{NS}	4.56^{x}	0.02^{NS}	0.01^{NS}	0.09^{NS}
Residual	69	15.95	1.86	32.31	325.00	1.11	0.02	0.01	0.02

NS = Not Significant. x = $P \leq 0.05$. xx = $P \leq 0.01$. xxx = $P \leq 0.001$

was significantly ($P < 0.05$) better than the unsupplemented cassava starch - Parkia diet.

Methionine supplementation also tended to significantly ($P < 0.01$) improve the protein efficiency ratio (PER), biological value (BV) and net protein utilisation (NPU) of all the proteins, irrespective of the starch source. The PER, BV and NPU were significantly ($P < 0.001$) higher for the casein than either the Parkia or Tamarindus diets, while the supplemented Parkia was significantly ($P < 0.01$) better than the Tamarindus diets.

All rats on the cocoyam diet died during the first three days of period of adjustment even before measurement were taken. These rats had diarrhoea and their gut contents contained very little food.

CHAPTER FOUR

4. DISCUSSION

4.1. CHEMICAL ANALYSIS

Generally, the results of the proximate and mineral analyses of both cassava and cocoyam obtained from this present study compare closely or are slightly higher than those reported by Oyenuga (1968), Tewe et. al., (1976), Tewe and Ajayi (1979), except in the cases of moisture, crude lipid and fibre contents for cocoyam and ash values for both cassava and cocoyam, where the values reported by Oyenuga (1968) were higher. The peels of both tubers contained more moisture than either the unpeeled or peeled tissues. Both tubers contain high amounts of carbohydrates and energy and this may explain why both are often widely used as major sources of energy in diets in various parts of the world (Dalziel, 1948; Pens, 1970; Standal, 1970; Franklin, 1970; Edgar, 1970; Obioha, 1972, Nestel et. al., 1975, Nestel, 1977 and Agboola, 1979).

The results of this study also showed that both cassava and cocoyam contain low amounts of crude protein, lipid and ash although, their mineral contents are fair. However, a higher protein content of 7.0 percent had been reported for a new cassava hybrid (Beck, 1971). It is believed that the traditional method of peeling the tuber crops before consumption adequately removes the high crude fibre in the peels while the

peeled portion which is high in organic matter, nitrogen - free - extracts, carbohydrate and energy is made available for use.

In contrast to the cassava and cocoyam, the higher crude protein contained in Parkia and Tamarindus seeds indicate their potentials as protein - rich foodstuffs (Oyenuga, 1968 and Fetuga et. al., 1974). Also, their high caloric values which were higher still than those of the cocoyam and cassava may be due to their higher contents of crude protein and lipids since these seeds had lower carbohydrate contents. The low moisture contents may be due to the fact that determination were done on already air-dried seed samples. Okeoma (1984) had reported higher moisture content (60-67.91 percent) for fermented Parkia seed nuts than was obtained in this present study.

Kapu (1980) and Eka (1980); Obodo (1982), Okeoma (1984) and Okpala (1985) variously reported crude protein, crude lipid and fibre values for both Parkia and Tamarindus seeds that were generally close to values obtained in this study. However, there were slight differences. For example, while the crude protein values (10.9-22.7 percent) for Tamarindus obtained by Kapu (1980) and Duke et. al., (1981), agree closely with the present results, the value (37.91 percent) reported by Obodo (1982) for unfermented Tamarindus nuts was very much higher although, the Tamarindus seeds used by Obodo (1982), Kapu (1980) and for the present investigation were sample from the same locality. The difference may be due

to analytical methods.

Also dehusking or shelling of the seeds and fermentation seemed to decrease the crude fibre and increase the protein and mineral contents of both seeds. This suggests that removal of the seed testa, followed by cooking and fermentation definitely improve the nutrient contents of the seeds (Fetuga, et. al., 1974 and Eka, 1980 and 1982). Although fermentation tended to lower the caloric value, this may not be considered a limitation of the fermentation process since fermented products are usually used to increase the protein quality and quantity of carbohydrate and energy-rich diets (Akinrele et. al., (1970) Eka, 1975; Eka and Kay, 1977; Akindele, 1978 and Okoh and Eka, 1978). In addition, cooking and fermentation have been found to reduce certain anti-nutritional factors in various foods and foodstuffs (Tewe et. al., 1976, Kay et. al., 1977; Eka, 1980 and 1982; Aletor, 1983 and Offiong, 1984). The present study also indicates that Parkia appears higher in nutrients than Tamarindus.

The low amino acid values for both cassava and cocoyam agree with literature values which show that these tubers are rich in arginine only (Oyenuga, 1968; Franklin, 1970 and Standal, 1970). Although, the crude protein contents in both Parkia and Tamarindus are high, their essential amino acid contents are fair when

compared to those of the reference protein, casein. This is not surprising since animal proteins such as casein usually have better amino acid patterns (Block and Mitchell, 1946 and FAO, (1970). The seeds contained higher amounts of virtually all amino acids than the root crops since legumious plants have root nodules for nitrogen fixation whereas root nodules are absent in the tuber crops. Also, their high contents of lysine, histidine and arginine are typical of seed legumes and the fact that they are low in methionine and the rest of the essential amino acids also agree with reported values for seed legumes (Altschul, 1962; Aykroyd and Doughty, 1964; Fetuga et. al., 1974, Abdi and Sahib, 1976; Felker and Bandurski, 1977 and Nierle and El-Baya, 1978).

Although, both seed legumes are from the same locality, the amino acid contents of Parkia were higher than those of the Tamarindus. The amino acid composition of Parkia agrees closely with previous workers (Fetuga et. al., (1974), Eka, 1980 and Okeoma, 1984). Whereas, the lack of literature on the amino acid composition of the Tamarindus further butresses the importance of this present research.

* Also from the determined values, it was not possible to readily differentiate between the molar ratios of the essential to non-essential amino acid (E.N.) and the essential amino acid to total nitrogen (E:T) values, for the low-protein cassava and cocoyam and the high-protein Parkia and Tamarindus seeds. This

is because the values for these chemical indices overlap. For example, the E:N values for cassava were even higher than that of the egg protein which was used as the standard, while corresponding values for Parkia and Tamarindus seeds were even lower than the egg and cassava values. Therefore, these chemical indices alone are probably not enough indicators for establishing the protein quality of these foodstuffs (Schneider and Flatt, 1975).

The limitation of the Block and Mitchell (1946) CS/PS is that it is based on just a single most limiting essential amino acid. Therefore, Oser (1951) who felt that all essential amino acids were equally important in their own right and should be considered because more than one essential amino acid may limit the effective use of a food protein, advocated for the use of the EAAI. Another advantage of the EAAI is that it was thought to correlate more closely with biological value (BV) than the CS/PS. Thus, the EAAI could be used to describe protein quality more effectively (Mitchell, 1954) than the CS/PS. But Oser's (1951) EAAI underscored the possibility of different rates of synthesis for those amino acids that could be formed, though at a sub-optimal rate (Crampton and Harris, 1968), the fact that at low levels of intake some amino acids are conserved (Bender, 1972) and methionine could replace cystine while cystin could not replace methionine.

However, the FAO/WHO expert group on protein requirements (1965) advised that since the CS/PS and EAAI were based on limiting essential amino acids only, it was better to use the E.P and E.T since the proportions of the limiting essential amino acids to the non-essential amino acids as well as the total nitrogen in food proteins were taken into consideration.

The fact is that none of these chemical methods of protein evaluation took into account the problem of digestibility, amino acid imbalances and antagonism (Schneider and Flatt, 1975). That is why their values cannot be taken as the only reliable assessment of true biological protein utilisation. However, this should not under-rate the fact that knowing the relative total amino acid composition of various food proteins is of empirical importance. Also, the knowledge of the essential amino acid distribution not only help as a guide in the fortification of deficient proteins with one or more pure amino acids but also is needed in the selection of suitable food protein supplements of dissimilar amino acid composition (Block and Mitchell, 1946 and Crampton and Harris, 1968).

4.2. BIOLOGICAL EVALUATION STUDIES

4.2.1. EXPERIMENT 1

Although, the feed and protein intake of rats on both the cocoyam and cassava - based diets were higher than those on the

corn starch - based diets, yet, weight gains of rats were higher for the corn starch - based diets than for the cassava and cocoyam - based diets. These poor weight gains for cassava - based diets seemed to agree with available literature (Tewe et. al., 1977, 1979 and 1981 and Job et. al., 1983) where, significantly ($P \leq 0.05$-0.01) depressed weight gains were reported for cassava - based diets when compared to corn starch - based diets. Oyenuga (1968) and Obioha (1972) blamed the poisonous effects of hydrocyanic acid contents of cassava for the poor performances of experimental animals. Similarly, the poor performances of rats on the cocoyam-based diets could also be attributed to the presence of oxalic acid and sapotoxins in the cocoyam (Jones, 1934, Oberdoffer, 1939 and 1940 and Dalziel, 1948). These anti-nutritional and toxic factors might not have been adequately removed during diet preparation.

Other reasons for poor rat performances might be attributed to the type of protein sources employed. For, the fact that the corn starch - casein diet gave better weight gain, feed conversion ratio (FCR), protein efficiency ratio (PER), biological value (BV) and net protein utilisation (NPU) than the cassava and cocoyam with Parkia or Tamarindus diets might indicate the superiority of the casein over Parkia and Tamarindus protein as well as corn starch over cassava and cocoyam starches. Furthermore, these results seemed to agree with those of Fetuga et. al., (1974) who employed Parkia seed protein in their experiment. Although, the Parkia and Tamarindus seed legumes have high crude protein,

deficiencies in their amino acid constituents which fell below requirements for the rat might have been responsible for the weight loss, low PER, FCR, BV and NPU values (Fetuga, 1972 and Fetuga et. al., 1974). However, results from the corn starch - Parkia diet showed that Parkia protein was better than Tamarindus protein. This might be due to the fact that Parkia had more protein and better amino acid pattern than Tamarindus. In all these cases, casein proved superior to both legume seeds since casein produced positive weight gain, better PCR, PER, BV and NPU, irrespective of the type of carbohydrate source. This supports the general belief that the amino acid composition of casein are more balanced than most plant proteins, Parkia and Tamarindus, inclusive. Also, the apparent digestibilities (AD) obtained in this study were lower than those of Fetuga et. al., (1974).

4.2.2. EXPERIMENT 2

Although, values for protein intake, weight gain, AD, FCR, PER, BV and NPU were still low, methionine supplementation tended to improve these biological indices for rats on both Parkia and Tamarindus diets. This probably indicates that methionine addition might have improved the balance in the amino acid contents of these seed proteins and hence increased their nutritive values. These results also showed that, like most leguminous seeds, Parkia and Tamarindus are deficient in Methionine. Performance on the Parkia

diets which was better then on the Tamarindus diets may be due to the higher contents of essential amino acids in the the Parkia than the Tamarindus. The fact that casein performance also improvedon methionine addition confirms the fact that casein too is deficient in methionine (Block and Mitchell, 1946).

Furthermore, these results seem to reveal that amino acid in-balances in the two seed legumes might not be completely corrected with only methionine supplementation, Earlier additional supplementation with tryptophan (Fetuga et. al., 1974) had been shown to improve rat performance on Parkia diets. This also seem to agree with literature information which indicates that most legume seeds are usually poor in methionine and also tryptophan (Abdi and Sahib, 1976, Felker and Bandurski, 1977, Nierle and El-Baya, 1978, Eka, 1980 and Okeoma, 1984).

Also, since cassava products are usually deficient in methionine (Oyenuga, 1968, Franlin, 1970 and Eggum, 1970), the overall deficiency in methionine might have further been aggravated. The same explanation might hold true for cocoyam diets. Other nutrients or factors may be involved in the overall nutritional values of diets based on these seeds. For example, Umoh and Oke (1974) obtained positive weight gains and PER, higher AD, BV and NPU with fermented Parkia seed nuts after extraction with chloroform, which removed organic acids. In addition, Eka (1980) had noted the presence of

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hydrocyanic, oxalic and phytic acids in Parkia seeds. This fact tends to show that such organic acids in the seeds may be anti-nutritionnal. The low biological indices for PER, BV and NPU reported in this investigation in both unsupplemented and methionine supplemented diets tend to agree with the results of Fetuga et. al., (1974), who did not extract the seeds.

Rats on the cocoyam diets in this experiment may have died due to starvation and diarrhoea. This explanation becomes laudable in view of little or no food in the gut of post-mortem animals. Little food was consumed probably because they did not find it acceptable and even the little that was eaten caused them severe diarrhoea. The rat carcasses also looked much emaciated.

During starch preparation, the cassava and cocoyam starches were autoclaved in order to deactivate any anti-nutritional factors and also to cook the starch. Autoclaving also killed micro-organisms. Probably more cooking time was needed for the cocoyam than for the cassava which was the sweet variety and may not have contained much cyanide. Therefore, it was possible that the young weanling rats could not stand the combined effects of the anti-nutritional factors (such as saponins), oxalic and hydrocyanic acids in both cocoyam and the legume seeds of the diets.

4.2.3. CONCLUSION

Results of the chemical analysis of this investigation clearly support the fact that cassava and cocoyam are higher-energy foodstuffs but according to the biological evaluation results, they may not adequately replace corn in either animal or human diets because they have lower crude protein content than cereals and possess some anti-nutritional or toxic factors as well. Therefore, before use, these root crops have to be properly processed in order to remove the anti-nutritional factors and then they could be used to only partially replace corn. Already, European feed compounders in Belgium, West Germany and the Netherlands have since been forced, due to cereal grain short falls, to use cassava chips and pellets, exported from Brazil, Thailand, Indonesia, East Africa and Nigeria as cheaper ingredients instead of cereals. This has enabled them to avoid sharp price increases while maintaining nutritional standards. This they do by mixing cassava with appropriate amounts of high - protein foodstuffs such as soybean meal and extract and produced a cheaper nutritious feed than could be produced if large quantities of cereals were used (Philips, 1974 and IDRC, 1975).

With such information and facts arising from the present results, it may be possible to use cocoyam, as well as cassava, along with enough quantities of fermented *Parkia* and *Tamarindus* seed nuts mixed with appropriate amounts of methionine-rich oilseeds such as beniseed (methionine content of 0.602%, Wilson *et. al.*, 1979) in both human

and animal feeds. This pertinently so when it is realised that as at now cassava and cocoyam, as well as Parkia and Tamarindus are available in large quantities and are cheaper than corn, other cereals and grain legumes.

4.2.4. Contributions to Knowledge

1. For the first time, both chemical and biological evaluation of the nutritional value of Tamarindus seeds were done.

2. The comparative evaluation of the amino acid composition of cassava, cocoyam, Parkia and Tamarindus were simultaneously done.

3. The feeding trial experiments indicated that methionine supplementation of Parkia and Tamarindus proteins may be beneficial to animals on cassava and cocoyam diets.

4.2.5. Suggestions for Future Research

1. The relatively poor performance of experiment rats on both cassava and cocoyam diets may be due to some anti-nutritional factors which were not adequately removed. A detailed chemical evaluation of such factors as tannins, oxalates, phytates, saponins and hydrocyanic acids will be necessary for both starch sources and seed legumes.

2. There is also the need for further feeding trials to determine the appropriate mix of tuber and standard carbohydrate sources on the one hand and seed legume and standard proteins on the other.

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Appendix 1

2.2.3. Chemical Analysis

2.2.3.1. Moisture and Dry Matter Determination

Moisture and dry matter contents of individual foodstuffs as well as the formulated diets were determined according to the procedure described by Oshorne et. al., (1978). Empty clean beakers, one each per sample, were dried in a hot air oven at 100°C for 30 minutes. Each beaker was then weighed (W1). Three to five grammes of the sample were placed in the beaker and then reweighed (W2). The beaker with the sample was then dried in an over at 60°C for 72 hours, during which time a constant weight was attained, and then transferred to a dessicator to cool. The beaker was quickly weighed with minimum exposure to the atmosphere (W3). The loss in weight of the sample during drying represented the moisture content, while the dry matter was the weight obtained after drying the sample. This is shown as below:

$$\text{Moisture\%} = \frac{W2-W3}{W2-W1} \times \frac{100}{1}$$

$$\text{Dry Matter (DM)\%} \frac{W3-W1}{W2-W1} \times \frac{100}{1}$$

2.2.3.2. Ash and Organic Matter Determination

The ash and organic matter of all samples were determined according to the method described by Osborne et. al., (1978). A clean, flat - bottomed silica dish was used per sample. The silica dish was dried in an oven at 100°C for five minutes, cooled in a dessicator and then weighed (W1).

Five grammes of the sample was placed in the dish and then reweighed (W2). The difference in weight was the waight of the sample (W2-W1). The dish with the sample was then gently heated on a bunsen-burner, in a fume cupboard until smoking stopped, and then transferred to a Muffle Furnace and heated to 550°C. Heating in the furnace was continued for twenty-four hours until all the carbon had been burnt off. Then the furnance was turned off, the dish with sample removed and covered to avoid contact with the atmosphere, was placed in a dessicator to cool and then weighed (W3). The weight of the sample after igniting in the furnance was the weight of the ash while that of the organic matter was the difference between the weight of the sample before and after heating in the furnance as shown below:

$$\text{Ash}\% = \frac{W3-W1}{W2-W1} \times \frac{100}{1}$$

$$\text{Organic Matter (OM)}\% = \frac{W2-W3}{W2-W1} \times \frac{100}{1}$$

2.2.3.3. Lipid (Fat) Content Determination

The lipid content of the food samples were determined, in duplicate, according to the Soxhlet method described by Osborne et. al., (1978). For each sample, a 500ml round-bottomed flash was weighed (Wa), a middle-sized thimble was weighed (Wb), then 3 grammes of the sample was accurately weighed into the thimble (Wc), 300mls of petroleum ether was carefully measured into the round bottomed flask. The thimble containing the sample was slotted into the extractor and the Soxhlet apparatus was set up. The extractor was connected to the round bottomed flask. Then both flask and extractor were connected to a reflux condenser and the oil in the sample was extracted under reflux, on a heating mantle, for three hours. At the end of the extraction, the Soxhlet was evaporated and the round bottomed flask with the fat residue was dried in an oven at 100°C for five minutes, cooled in a dessicator and reweighed (Wd). The thimble was also dried in the oven at 60°C for 24 hours and then weighed (We). The weight of the fat extracted is the weight of flask after extraction minus that before extraction:

$$\text{Fat (Lipid)\%} = \frac{Wd-Wa}{Wt_r \text{ of sample}} \times 100$$

2.2.3.4. Crude Fibre Determination

The crude fibre content of each sample was determined by the Instrumental Method using the Fibertec System, Model 1010 Heat Extractor, at the National Animal Production Research Institute (NAPRI), Shika. The chemical procedure used was the modified Weende Method (AOAC, 1970) described as follows:-

2 grammes of the defatted sample was put into 200mls of 1.25% (0.255N) sulphuric acid and boiled under reflux for exactly 30 minutes. The hot solution was quickly filtered under suction. The insoluble matter was washed several times with distilled water until it was acid free as determined by using Litmus paper. It was then transferred into 200mls preheated 1.25% (0.312N) Sodium hydroxide solution, boiled again under reflux for exactly 30 minutes and quickly filtered under suction (541 filter papers were used for all filtrations). The insoluble residue was first washed with boiling water, followed by 1% hydrochloric acid and again with boiling water until acid free. It was then washed several times with alcohol (95-96% industrial methylated spirits) and finally with diethyle ether, dried to a constant weight at 100°C in an oven and weighed. This weight represented the fibre and ash content of the sample. The sample was ashed in a Muffle Furnace at 600°C for 2

hours, cooled in a dessicator and reweighed. The loss in weight was calculated as the percentage fibre content according to the following equation:

$$\text{Crude fibre \%} = \frac{\text{loss in weight on ashing}}{\text{Original sample weight.}} \times 100$$

2.2.3.5. Nitrogen and Crude Protein Determination

The Nitrogen determination was done according to the micro kjeldahl method described by Bradstreet (1957).

100mg of each sample was weighed into a 100ml kjeldahl flask, and a few glass regulators were added. 1g of the mixed catalyst which had been prepared using 160g of potassium sulphate, 10g of copper sulphate and 3g of selenium powder, was added into the flask. 5mls of concentrated sulphuric acid was carefully added and mixed gently with the contents in the flask.

The flask was placed on a kjeldahl digestion rack and heated for 20 minutes. The flask was heated slowly at first until frothing subsided and then heated more vigorously, occasionally rotating the flask, to ensure even digestion and over-heating of the contents. At the end of 20 minutes, the mixture in the flask had become clear and a white slurry was noticed at the bottom of the flask. Heating was then continued for another one hour. At the end of the digestion period, the heat was turned off and the flask was allowed to cool. 15mls of distilled water was cautiously

added to the digest. The digest was again allowed to cool. Then it was transferred quantatively into a 50ml volumetric flask. The kjeldahl flask was rinsed out with distilled water into the volumetric flask but leaving behind the glass regulators in the kjeldahl flask. The digest in the volumetric flask was then made up to mark.

10mls of the digest was pipetted into the Markham semi-micro nitrogen still and 10mls of 50% Sodium hydroxide solution was added cautiously. This was steam distilled, liberating ammonia into a 50ml conical flask containing 5ml 2% boric acid (2g in 100mls) and 3 drops of mixed indicator (99mg bromo-cresol green, 66mg methyl red and 11mg thymol blue dissolved in 10mls ethanol). The indicator turned green and distillation was continued for another 2 minutes.

The content of the conical flask was titrated with 0.07M Hydrochloric acid. The end-point was when the indicator changed from green to a definite pink or voilet colour. The volume of the acid used for each distillate was noted. Duplicate samples and blanks were also done.

Percentage total nitrogen per sample was calculated using the following for formula:

$$\text{i.e. } V_2 - V_1 \times M \times \frac{14}{1000} \times \frac{50}{10} \times \frac{100}{1}$$

where;

V_1 = volume of hydrochloric acid required for the blank

V_2 = volume of hydrochloric acid required for 10mls sample solution

100 = to convert to percent

M = molarity of Hydrochloric acid

= 0.07M.

50ml = total volume of digest

10ml = volume distilled

1000 = to convert ml to litres

14 = atomic weight of nitrogen

Then crude protein was calculated as shown below:

crude protein (CP)% = 6.25 x Nitrogen %.

6.25 is the conversion factor since it is assumed that proteins contain 16% nitrogen.

Appendix 2

Calculation of 10 percent protein levels in Casein Parkia and Tamarindus

Average protein content of casein is 86.35g percent

100g Casein gives 86.35g protein

? " " 10g protein

$\frac{100 \times 10}{86.35} = 11.58g$ Casein

In 100g diet there are 11.58g casein

in 1000g diet there are $\frac{11.58}{100} \times \frac{1000}{1}$

$= 115.8g$ casein

So in 1000g (1kg) diet, 115.8g casein was in-corporated at the expense of the starch.

Fermented Parkia clappertoniana seeds contain 46.0% protein

100g gives 46.0g protein

$\frac{100 \times 10g}{46.0}$ gives 10.0g protein

In 100g diet, there is $\frac{1000g \text{ Parkia}}{46}$

1000g diet contains $\frac{1000}{46} \times \frac{1000}{100}$

$= 217.39g$

In 1000g (1kg) diet, 217.39 Parkia clappertoniana seeds was in-corporated at the expense of the starch.

Fermented Tamarindus indica contains 19.54% protein

100g gives 19.54g protein

$\frac{100 \times 10g}{19.54}$ gives 10g protein

In 1000g (1kg) diet, there is

$\frac{1000}{100} \times \frac{1000g}{19.54} = 511.77g$

In 1000g (1kg) diet, 511.77 of Tamarindus indica seeds was in in-corporated at the expense of the starch.

APPENDIX 3: Protein Quality of Fermented Parkia and Tamarind Seed nuts, with casein as the reference protein, using cornstarch

		A	B	C	D	E	F*	G	H	I	J	K	L	M
Diets	Rats	Weight Change	Total feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water: Nitrogen Ratio	AD	FCR	PER	BV	NPU
Corn Starch Only	CS[1]	-1.1g	28.1g	1.19g	0.36g	26.8g	18.9[70.52]	0.66[2.46]	28.68	69.50				
	CS[2]	-0.6	22.5	0.96	0.26	27.7	19.5[70.39]	0.75[2.71]	26.00	72.90				
	CS[3]	-0.5	23.3	0.95	0.36	33.6	23.3[69.35]	0.95[2.83]	24.53	61.90				
Non-Protein diet	CS[4]	-1.1	16.5	0.70	0.16	37.5	25.4[67.73]	1.04[2.76]	24.42	77.10				
	CS[5]	-4.6	14.5	0.61	0.13	34.9	23.7[67.90]	0.97[2.77]	24.43	78.69				
	CS[6]	-1.8	19.8	0.84	0.25	28.7	19.7[68.64]	0.80[2.80]	24.63	70.40				
Corn Starch + Casein diet	CSCN[1]	9.3g	26.00g	2.60g	0.48g	29.8g	21.4[71.81]	0.87[2.93]	24.60	81.54	2.80	3.58	0.47	0.38
	CSCN[2]	9.4g	24.90	2.49	0.46	29.6	21.3[71.91]	0.87[2.94]	24.48	81.52	2.65	3.78	0.49	0.40
	CSCN[3]	8.8	56.5	5.65	0.81	39.0	26.5[67.95]	1.08[2.77]	24.54	85.66	6.40	1.56	0.48	0.41
	CSCN[4]	2.9	17.50	1.75	0.40	32.4	22.6[69.75]	0.92[2.85]	24.57	77.14	6.00	1.66	0.97	0.75
	CSCN[5]	2.0	7.50	0.75	0.20	25.2	18.2[72.22]	0.74[2.95]	24.59	73.33	3.80	0.27	0.34	0.25
	CSCN[6]	3.3	15.8	1.58	0.30	25.5	18.2[71.37]	0.74[2.91]	24.59	81.00	4.80	0.21	0.36	0.25

*Lower cases = in grammes

Upper cases = in percentage

(Appendix 3 continued)

Diets	Rats	Weight Change (g)	Total Feed Consumed (g)	Protein Consumed (g)	Faecal Protein (g)	Live Weight (g)	Carcass Water Content	Carcass Nitrogen Content	Water: Nitrogen Ratio	AD	PCR	PER	BV	NPU
Corn	CSPA[1]	-0.1	3.3	3.33	0.09	35.9	$25.1^{69.92}$	$0.93^{2.58}$	26.99	72.43	33.02	-0.03	0.32	0.23
Starch	CSPA[2]	+1.5	47.0	4.70	1.05	38.2	$16.6^{69.63}$	$0.91^{2.38}$	18.24	77.68	31.3	0.31	0.39	0.28
+	CSPA[3]	+1.4	62.1	6.21	1.99	40.5	$28.4^{70.12}$	$0.94^{2.32}$	30.21	83.41	44.4	0.23	0.48	0.32
Pereira diet	CSPA[4]	+1.5	23.4	2.34	0.46	31.4	$21.8^{69.43}$	$0.83^{2.64}$	26.27	80.34	15.6	0.64	0.21	0.17
	CSPA[5]	+1.9	61.6	6.16	1.03	38.1	$26.0^{68.24}$	$1.07^{2.82}$	24.30	83.28	32.4	0.31	0.44	0.36
	CSPA[6]	+1.5	62.1	6.21	1.69	37.0	$25.2^{68.11}$	$1.03^{2.78}$	24.47	72.85	41.4	0.24	0.44	0.32
	CSTA[1]	-2.2	6.3	0.63	0.11g	25.5g	$18.1^{70.98}$	$0.69^{2.71}$	26.23	82.54	2.86	-3.40	0.28	0.20
Corn	CSTA[2]	-12.3	32.0	3.20	0.50	21.8	$14.7^{67.43}$	$0.71^{3.26}$	20.70	84.17	2.60	-3.84	0.29	0.23
Starch	CSTA[3]	-4.4	39.0	3.90	1.10	27.2	$19.3^{70.96}$	$0.71^{2.61}$	27.18	71.79	8.86	-1.13	0.29	0.23
+														
Tamarind	CSTA[4]	-2.6	12.1	1.21	0.31	28.0	$21.7^{77.50}$	$0.74^{2.65}$	29.32	74.38	4.65	-2.20	0.22	0.16
diet	CSTA[5]	-1.4	19.4	1.94	0.36	30.2	$21.9^{72.52}$	$0.80^{2.65}$	27.38	81.14	13.86	-0.72	0.36	0.29
	CSTA[6]	-3.4	25.0	2.50	0.50	23.8	$17.4^{73.11}$	$0.61^{2.56}$	28.52	80.00	7.35	-1.36	0.31	0.25

(Appendix 3 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	AD	PCR	PER	BV	NPU
	CA[1]	-7.5g	26.8g	0.27	0.07	35.5	$23.0^{70.43}$	$0.94^{2.64}$	24.47	74.07				
Cassava Starch only Non-protein diet	CA[2]	-6.8	30.7	0.31	0.08	34.0	$24.4^{71.76}$	$1.00^{2.93}$	24.40	74.19				
	CA[3]	-5.8	27.0	0.27	0.07	36.0	$26.0^{72.22}$	$1.02^{2.84}$	25.49	74.07				
	CA[4]	-13.5	12.5	0.13	0.03	36.4	$24.9^{68.41}$	$1.02^{2.79}$	24.41	76.92				
	CA[5]	-11.5	17.0	0.17	0.04	38.4	$26.7^{69.53}$	$1.08^{2.84}$	24.72	76.47				
	CA[6]	-6.0	12.3	0.12	0.03	36.0	$25.8^{71.67}$	$1.05^{2.92}$	24.57	75.00				
Cassava Starch + Casein diet	CACN[1]	2.7g	43.7g	4.37g	1.22g	45.2g	$30.4^{67.26}$	$1.24^{2.74}$	24.52	72.08	16.19	0.62	0.50	0.36
	CACN[2]	6.4g	54.4	5.44	1.44	47.6	$32.7^{69.00}$	$1.33^{2.86}$	24.59	73.53	8.50	1.18	0.53	0.39
	CACN[3]	2.0	83.2	8.32	0.31	40.5	$28.7^{70.86}$	$1.67^{2.04}$	17.19	96.27	41.60	0.24	0.56	0.51
	CACN[4]	4.1	30.9	3.09	0.39	41.2	$29.0^{70.39}$	$1.18^{2.87}$	24.58	87.38	7.54	1.33	0.43	0.38
	CACN[5]	7.0	18.9	1.89	0.31	34.5	$24.2^{70.14}$	$0.99^{2.86}$	24.44	83.60	2.70	3.70	0.49	0.40
	CACN[6]	7.1	31.2	3.12	0.57	41.4	$28.7^{69.32}$	$1.17^{2.83}$	24.53	81.73	4.40	2.28	0.44	0.36

(Appendix 3 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	AD	FCR	PER	BV	NPU
Cassava Starch + Prolin diet	CAPA[1]	-3.0g	20.6g	2.06g	0.75g	35.0g	$23.5^{65.71}$	$0.96^{2.74}$	24.48	63.60	6.87	-1.46	0.14	0.09
	CAPA[2]	-5.5	37.0	3.70	0.53	30.5	$22.5^{73.77}$	$0.92^{3.01}$	24.46	85.68	6.73	-1.49	0.18	0.12
	CAPA[3]	-7.0	36.3	3.63	0.81	33.0	$21.8^{66.06}$	$0.89^{2.70}$	24.49	77.69	5.19	-2.08	0.22	0.17
	CAPA[4]	-5.2	30.0	3.00	0.65	30.0	$21.0^{70.00}$	$0.86^{2.86}$	24.42	77.33	5.77	-1.73	0.35	0.27
	CAPA[5]	-3.4	14.1	1.41	0.38	30.0	$22.2^{74.00}$	$0.91^{3.02}$	24.40	74.47	4.15	-2.41	0.48	0.35
	CAPA[6]	-4.8	23.4	2.34	0.59	39.7	$27.0^{68.01}$	$1.10^{2.77}$	24.55	74.79	4.88	-2.05	0.43	0.30
Cassava starch + Tamarind diet	CATA[1]	-5.0g	55.3	5.53g	1.53	33.0	$20.0^{60.60}$	$0.77^{2.33}$	25.97	72.33	11.06	-0.94	0.35	0.25
	CATA[2]	-5.0	50.0	5.00	1.00	30.0	$20.5^{68.33}$	$0.79^{2.63}$	25.95	80.00	10.00	-1.00	0.31	0.25
	CATA[3]	-5.1	57.0	5.70	1.10	27.2	$19.0^{69.85}$	$0.73^{2.69}$	26.03	80.70	11.22	-0.88	0.36	0.29
	CATA[4]	-5.1	64.0	6.40	1.30	34.0	$19.7^{57.94}$	$0.76^{2.23}$	25.92	79.68	2.55	-0.80	0.29	0.23
	CATA[5]	-4.5	52.0	5.20	0.90	32.0	$21.4^{66.87}$	$0.82^{2.57}$	26.10	82.69	11.56	-0.87	0.23	0.19
	CATA[6]	-4.9	55.7	5.57	1.17	31.2	$20.1^{64.72}$	$0.77^{2.49}$	25.99	79.08	11.28	-0.90	0.31	0.24

(Appendix 3 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	AD	FCR	PER	BV	NPU
Cocoyam Starch only non-Protein diet	CO[1]	-4.0g	22.0g	0.088g	0.032g	31.0g	17.0[54.84]	0.69[2.23]	24.64	63.64				
	CO[2]	-12.2	22.0	0.088	0.030	26.3	14.0[53.23]	0.50[1.90]	28.00	65.91				
	CO[3]	-5.2	23.0	0.092	0.035	25.5	15.5[60.78]	0.63[2.48]	24.60	61.96				
	CO[4]	-5.8	27.2	0.100	0.040	32.2	16.2[50.31]	0.66[2.05]	24.55	63.30				
	CO[5]	-1.2	13.4	0.054	0.020	28.0	14.5[51.78]	0.59[2.11]	24.58	62.96				
	CO[6]	-4.0	18.4	0.074	0.024	30.6	16.0[52.28]	0.65[2.13]	24.62	67.58				
Cocoyam Starch Protein diet	COCN[1]	5.0g	43.0g	4.30g	0.85	32.1g	21.5[67.19]	0.88[2.74]	24.43	80.23	8.60	1.16	0.49	0.39
	COCN[2]	3.0	34.7	3.47	0.75	30.0	19.5[65.00]	0.80[2.65]	24.38	78.39	11.57	0.87	0.43	0.34
	COCN[3]	8.9	104.6	10.46	1.81	51.8	36.5[70.46]	1.49[2.87]	24.50	82.84	11.75	0.76	0.64	0.53
	COCN[4]	3.5	39.2	3.92	0.64	30.5	20.5[67.21]	0.84[2.74]	24.40	83.67	11.20	0.89	0.44	0.37
	COCN[5]	4.0	59.1	5.91	0.95	32.5	22.7[69.85]	0.93[2.85]	24.41	83.93	14.78	0.76	0.41	0.34
	COCN[6]	4.8	72.1	7.21	1.09	33.8	24.9[71.01]	0.98[2.90]	24.49	84.88	15.00	0.67	0.38	0.32

(Appendix 3 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	AD	FCR	PER	BV	NPU
Cocoyam Starch + Pawpaw diet	COPA[1]	-11.0g	12.0g	1.20	0.28g	25.0	$15.8^{63.20}$	$0.64^{2.58}$	24.69	76.67	1.09	-9.17	0.21	0.16
	COPA[2]	-3.3	83.0	8.30	1.64	34.0	$22.6^{66.47}$	$0.92^{2.71}$	24.57	80.24	25.15	-0.40	0.29	0.23
	COPA[3]	-4.0	43.7	4.37	1.55	27.5	$18.0^{65.45}$	$0.73^{2.69}$	24.66	64.53	10.93	-0.92	0.26	0.17
	COPA[4]	-3.4	88.3	8.83	1.77	36.5	$24.8^{67.94}$	$1.01^{2.76}$	24.55	79.95	25.97	-0.39	0.35	0.28
	COPA[5]	-3.2	97.4	9.74	1.85	37.3	$25.7^{68.90}$	$1.05^{2.81}$	24.48	81.06	30.43	-0.33	0.35	0.28
	COPA[6]	-8.9	26.3	2.63	0.73	24.7	$15.7^{63.56}$	$0.64^{2.59}$	24.53	72.24	2.96	-3.38	0.10	0.07
Cocoyem Starch + Tamarind diet	COTA[1]	-11.1g	34.1	3.41g	0.51	26.0	$18.0^{69.23}$	$0.73^{2.82}$	24.66	85.04	3.07	-3.26	0.26	0.22
	COTA[2]	-1.0	41.3	4.13	0.73	25.7	$19.5^{75.88}$	$0.80^{3.10}$	24.34	82.32	41.30	-0.24	0.35	0.29
	COTA[3]	-5.1	55.7	5.57	1.00	29.0	$20.7^{71.38}$	$0.84^{2.91}$	24.64	83.66	11.14	-0.90	0.31	0.26
	COTA[4]	-3.7	21.1	2.11	0.91	24.8	$16.0^{65.32}$	$0.66^{2.67}$	24.24	56.87	5.70	-1.42	0.23	0.13
	COTA[5]	-3.9	21.6	2.16	0.88	23.5	$16.6^{70.64}$	$0.68^{2.88}$	24.41	59.26	5.54	-1.81	0.41	0.20
	COTA[6]	-4.9	34.76	3.48	0.81	25.8	$18.2^{70.49}$	$0.74^{2.86}$	24.46	73.43	13.35	-1.53	0.31	0.22

APPENDIX 4: **Experiment** 2: **Protein Quality of Fermented Parkia and Tamarind Seed Nuts Supplemented with Methionine Using Corn Starch**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass H2O Content	Carcass N2 Content	Water Nitrogen Ratio	FCR	PER	AD	BV	NPU
	CS[1]	-7.7g	8.8g	0.37	0.09	23.0g	$16.6^{72.17}$	$0.68^{2.94}$	24.41			75.67		
	CS[2]	-7.4	10.1	0.43	0.15	23.2	$16.8^{72.41}$	$0.69^{2.95}$	24.35			65.12		
	CS[3]	-1.1	6.6	0.28	0.05	22.4	$15.2^{67.86}$	$0.62^{2.76}$	24.52			82.14		
X	CS[4]	-1.0	23.0	0.97	0.30	34.0	$23.7^{69.71}$	$0.97^{2.84}$	24.43			69.07		
	CS[5]	-0.5	21.6	0.91	0.20	36.0	$25.6^{71.10}$	$1.04^{2.90}$	24.62			71.43		
	CS[6]	-0.8	18.20	0.77	0.22	29.9	$21.6^{72.24}$	$0.88^{2.95}$	24.55			71.43		
CSCN[1]	5.9	26.0	2.60	0.40	29.6	$20.8^{70.27}$	$0.84^{2.86}$	24.76	5.20	2.27	84.62	0.37	0.31	
CSCN[2]	5.1	25.3	2.53	0.28	26.0	$19.8^{76.15}$	$0.80^{3.10}$	24.75	4.96	2.02	88.93	0.23	0.23	
CSCN[3]	7.8	36.3	3.63	0.60	37.0	$25.1^{07.84}$	$1.02^{2.77}$	24.60	4.65	2.15	86.23	0.61	0.53	
CSCN[5]	5.1	18.3	2.65	0.55	28.7	$20.2^{70.38}$	$0.82^{2.87}$	25.25	5.23	1.91	79.23	0.33	0.26	
CSCN[6]	5.99	20.4	2.98	0.57	30.9	$22.0^{71.20}$	$0.89^{2.90}$	24.72	4.98	2.01	79.90	0.48	0.38	
CSCNM[1]	7.2	29.5	2.95	0.61	31.9	$22.0^{68.97}$	$0.90^{2.84}$	24.44	4.10	2.44	80.00	0.51	0.41	
CSCNM[2]	9.3	38.7	3.87	0.98	35.1	$25.3^{72.02}$	$1.03^{2.94}$	24.36	4.16	2.40	74.73	0.69	0.52	
CSCNM[3]	5.8	24.3	2.43	0.39	28.1	$20.0^{71.17}$	$0.82^{2.90}$	24.39	4.19	2.39	84.30	0.33	0.28	
CSCNM[4]	7.5	30.0	3.00	0.44	31.7	$22.7^{71.61}$	$0.93^{2.92}$	24.41	4.00	2.50	85.33	0.54	0.46	
CSCNM[5]	10.7	49.5	4.95	0.48	36.0	$26.0^{72.22}$	$1.06^{2.95}$	24.53	4.63	2.16	90.30	0.49	0.44	
CSCNM[6]	13.3	49.1	4.91	0.45	43.8	$31.2^{71.23}$	$1.27^{2.91}$	24.57	3.69	2.71	90.83	0.78	0.71	

(Appendix 4 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	AD	FCR	PER	BV	NPU
Corn Starch + Perkin diet	CSPA[1]	+4.1g	60.6g	6.06g	1.51g	37.6g	$25.6^{68.09}$	$1.04^{2.78}$	24.62	75.08	14.78	+0.67	0.46	0.34
	CSPA[2]	+0.7	55.2	5.52	0.92	30.4	$22.2^{73.03}$	$0.91^{2.98}$	24.40	83.33	78.86	+0.13	0.28	0.23
	CSPA[3]	-5.5	17.7	1.77	0.27	20.4	$14.3^{70.10}$	$0.58^{2.86}$	24.66	84.73	3.22	-3.11	0.54	0.46
	CSPA[4]	-0.7	29.1	2.91	0.54	34.5	$23.0^{66.66}$	$0.94^{2.72}$	24.47	81.44	4.16	-0.24	0.60	0.49
	CSPA[5]	+4.0	21.0	2.10	0.60	24.7	$17.6^{71.26}$	$0.72^{2.91}$	24.44	71.43	5.25	+1.91	0.04	0.03
	CSPA[6]	+1.0	24.5	2.45	0.60	26.0	$18.7^{71.92}$	$0.76^{2.93}$	24.61	75.51	24.50	+0.41	0.17	0.13
Corn Starch + Perkin + Methionine diet	CSPAM[1]	11.6g	61.30	6.13	1.33g	36.5	$26.1^{71.51}$	$1.06^{2.92}$	24.62	78.30	5.44	1.92	0.46	0.36
	CSPAM[2]	5.4	44.3	4.43	0.93	33.6	$23.6^{70.23}$	$0.96^{2.87}$	24.58	79.01	8.20	1.22	0.44	0.35
	CSPAM[3]	2.7	25.5	2.55	0.75	26.7	$19.3^{72.28}$	$0.79^{2.95}$	24.43	70.59	9.44	1.06	0.28	0.20
	CSPAM[4]	6.6	64.2	6.42	1.42	40.9	$28.2^{68.95}$	$1.15^{2.81}$	24.52	77.88	9.73	1.03	0.55	0.43
	CSPAM[5]	5.6	52.4	5.24	1.50	28.7	$20.1^{70.03}$	$0.82^{2.86}$	24.51	71.37	9.37	1.07	0.18	0.13
	CSPAM[6]	4.3	42.0	4.20	1.20	32.6	$22.8^{69.94}$	$0.93^{2.85}$	24.26	71.42	9.77	1.02	0.46	0.33
Corn Starch + Tamarind diet	CSTA[1]	-0.6g	14.6g	1.46g	0.54	36.0	$24.7^{68.61}$	$1.01^{2.80}$	24.45	63.01	24.33	-0.41	0.21	0.13
	CSTA[2]	-5.2	11.4	1.14	0.36	22.2	$16.5^{74.32}$	$0.67^{3.03}$	24.63	68.42	2.19	-4.56	0.32	0.22
	CSTA[3]	-4.0	20.5	2.05	0.43	34.9	$22.0^{63.04}$	$0.85^{2.43}$	25.88	79.02	5.13	-1.95	0.54	0.42
	CSTA[4]	-3.4	19.5	1.95	0.36	32.4	$19.7^{60.80}$	$0.76^{2.34}$	25.92	81.15	5.74	-1.74	0.20	0.16
	CSTA[5]	-8.5	22.3	2.23	0.34	30.5	$18.2^{59.67}$	$0.71^{2.31}$	25.63	84.48	2.62	-3.81	-	-
	CSTA[6]	-4.4	18.6	1.86	0.38	34.0	$22.0^{64.32}$	$0.75^{2.21}$	29.33	79.57	4.23	-2.37	0.17	0.13

(Appendix 4 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	AD	PCR	PER	BV	NPU
Corn Starch + Tamarind + Methionine	CSTAM[1]	0.0	106.50g	10.65g	2.65	43.7	$31.0^{70.94}$	$1.19^{2.73}$	26.05	75.12	-	-	0.37	0.28
	CSTAM[2]	0.0	72.28	7.23	1.78	37.7	$27.3^{72.41}$	$1.05^{2.79}$	26.00	75.55	-	-	0.38	0.29
	CSTAM[3]	-0.8	78.8	7.88	1.88	36.9	$26.5^{71.82}$	$1.02^{2.76}$	25.98	76.14	98.50	0.10	0.32	0.24
	CSTAM[4]	+2.0	80.7	8.07	1.87	35.7	$25.7^{71.99}$	$0.99^{2.77}$	25.96	76.83	40.35	0.25	0.29	0.22
	CSTAM[5]	+2.4	75.7	7.57	1.99	35.7	$23.5^{65.83}$	$0.90^{2.53}$	26.11	73.71	31.54	0.32	0.22	0.16
	CSTAM[6]	+1.00	50.5	5.05	1.05	30.7	$22.7^{73.94}$	$0.87^{2.85}$	26.09	72.73	50.50	0.20	0.27	0.20
Cassava Starch only non-protein diet	CA[1]	-7.5g	34.5g	0.43g	0.08g	26.5g	$18.3^{69.05}$	$0.75^{2.82}$	24.40	81.20				
	CA[2]	-9.5	45.0	0.56	1.00	27.0	$19.5^{72.22}$	$0.80^{2.95}$	24.38	82.14				
	CA[3]	-8.0	35.5	0.44	0.09	29.0	$20.0^{68.96}$	$0.82^{2.81}$	24.39	79.55				
	CA[4]	-3.7	11.8	0.15	0.05	32.0	$22.7^{70.94}$	$0.87^{2.72}$	26.09	66.67				
	CA[5]	-12.0	45.0	0.56	1.00	26.0	$17.6^{67.69}$	$0.72^{2.76}$	24.44	82.14				
	CA[6]	-10.5	40.0	0.50	0.12	29.4	$20.2^{68.71}$	$0.82^{2.80}$	24.63	76.00				
Cassava Starch + Casein	CACN[1]	1.3g	26.2g	2.62g	0.38	32.5	$22.2^{68.31}$	$0.96^{2.95}$	23.13	85.5	20.15	0.50	0.64	0.55
	CACN[2]	1.0	41.0	4.10	0.43	38.9	$26.9^{69.15}$	$1.10^{2.82}$	24.45	89.51	41.00	0.24	0.62	0.56
	CACN[3]	4.7	29.7	2.97	0.56	35.2	$24.8^{70.45}$	$1.01^{2.87}$	24.55	81.14	6.32	1.58	0.71	0.58
	CACN[4]	4.3	36.3	3.63	0.49	39.6	$27.7^{69.95}$	$1.13^{2.85}$	24.51	86.50	8.44	1.18	0.80	0.69
	CACN[5]	3.5	22.0	2.20	0.60	31.6	$21.6^{68.35}$	$0.88^{2.79}$	24.55	72.73	6.29	1.60	0.59	0.43
	CACN[6]	7.0	35.0	3.50	0.55	37.0	$26.3^{71.08}$	$1.07^{2.90}$	24.58	84.28	5.00	2.00	0.72	0.61

(Appendix 4 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	TD	FCR	PER	BV	NPU
	CACNM[1]	10.8g	40.4g	4.04g	0.82	40.6	$27.5^{67.75}$	$1.12^{2.76}$	24.55	80.26	3.74	2.67	0.75	0.60
Cassava Starch + Casein + Methionine	CACNM[2]	25.0	85.0	8.50	1.50	53.9	$40.4^{74.95}$	$1.64^{3.06}$	24.63	82.35	3.40	2.94	0.83	0.68
	CACNM[3]	18.7	60.9	6.09	0.59	50.3	$37.0^{73.56}$	$1.50^{2.97}$	24.67	90.31	3.26	3.07	0.87	0.79
	CACNM[4]	16.3	64.7	6.47	1.07	48.9	$35.4^{72.39}$	$1.44^{2.95}$	24.58	83.46	3.97	2.52	0.83	0.69
	CACNM[5]	28.3	96.2	9.62	0.60	57.2	$41.9^{73.25}$	$1.71^{2.99}$	24.50	83.16	3.40	2.94	0.77	0.64
	CACNM[6]	-3.7	44.7	4.47	0.97	36.9	$25.4^{68.83}$	$1.04^{2.81}$	24.42	78.39	12.08	-0.08	0.56	0.43
	CAPA[1]	-2.8g	48.7g	4.87g	0.86	40.6g	$27.0^{66.50}$	$1.10^{2.71}$	24.55	82.34	17.39	-0.57	0.57	0.47
Cassava Starch + Peptic + Methionine	CAPA[2]	-5.8	36.5	3.65	0.68	32.6	$21.6^{66.26}$	$0.88^{2.70}$	24.55	81.37	6.29	-1.59	0.32	0.26
	CAPA[3]	-9.4	57.1	5.71	1.17	37.8	$25.8^{68.25}$	$1.11^{2.92}$	23.24	79.51	6.07	-1.65	0.53	0.42
	CAPA[4]	-2.5	62.8	6.28	1.86	42.1	$27.6^{65.85}$	$1.13^{2.67}$	24.42	70.06	25.12	-1.95	0.54	0.38
	CAPA[5]	-4.0	23.3	2.33	0.58	32.5	$21.4^{65.85}$	$0.87^{2.68}$	24.60	75.11	5.83	-0.40	0.51	0.38
	CAPA[6]	-1.5	58.0	5.80	0.81	38.0	$25.7^{67.63}$	$1.05^{2.76}$	24.48	86.03	38.67	-0.26	0.40	0.34
	CAPAM[1]	1.3g	91.9g	9.19g	1.55g	33.4g	$22.9^{68.56}$	$0.93^{2.80}$	24.62	83.13	70.69	0.14	0.49	0.41
Cassava Starch + Peptic + Methionine	CAPAM[2]	2.1	44.5	4.45	0.89	36.4	$25.9^{71.15}$	$1.06^{2.90}$	24.43	80.17	21.19	0.47	0.57	0.46
	CAPAM[3]	2.0	35.0	3.50	0.81	35.0	$23.6^{67.43}$	$0.96^{2.75}$	24.58	76.86	21.19	0.57	0.53	0.41
	CAPAM[4]	2.0	30.3	3.03	0.76	32.1	$21.8^{67.91}$	$0.89^{2.71}$	24.49	74.92	15.15	0.61	0.44	0.33
	CAPAM[5]	2.0	31.0	3.10	0.65	34.0	$23.6^{69.41}$	$0.96^{2.83}$	24.58	79.03	15.50	0.65	0.58	0.46
	CAPAM[6]	2.5	29.8	2.98	0.59	32.5	$22.1^{68.00}$	$0.90^{2.77}$	24.56	80.20	11.92	0.84	0.46	0.37

(Appendix 4 Continued)

Diets	Rats	Weight Change	Total Feed Consumed	Protein Consumed	Faecal Protein	Live Weight	Carcass Water Content	Carcass Nitrogen Content	Water Nitrogen Ratio	A_D	FCR	PER	BV	NPU
Cassava + Tamarind + Methionine	CATA[1]	-3.0g	20.1g	1.01g	0.64	34.0	$21.1^{62.06}$	$0.81^{2.39}$	26.05	68.16	6.70	-1.49	0.37	0.25
	CATA[2]	-8.0	30.5	3.05	0.51	28.0	$19.3^{68.93}$	$0.74^{2.65}$	26.08	83.33	3.81	-2.62	0.02	0.02
	CATA[3]	-2.0	13.2	1.32	0.51	28.0	$19.7^{70.36}$	$0.76^{2.71}$	25.92	61.36	6.60	-1.52	0.23	0.14
	CATA[4]	-3.0	22.1	2.21	0.49	30.0	$21.7^{72.33}$	$0.84^{2.78}$	25.83	77.83	7.37	-1.36	0.40	0.31
	CATA[5]	-2.0	19.2	1.92	0.75	35.0	$19.5^{54.29}$	$0.76^{2.15}$	25.66	60.94	9.60	-1.04	0.16	0.10
	CATA[6]	-	-	-	-	-	-	-	-	-	-	-	-	-
	CATAM[1]	+2.0g	31.7g	3.17	1.05	42.9	$21.4^{49.90}$	$0.82^{1.92}$	26.10	66.88	15.85	+0.63	0.27	0.18
	CATAM[2]	-0.4	47.3	4.73	1.23	40.3	$27.8^{68.98}$	$1.07^{2.66}$	25.98	74.00	118.25	-0.08	0.60	0.45
	CATAM[3]	-5.0	50.5	5.05	0.85	34.9	$24.0^{68.77}$	$0.92^{2.65}$	26.09	83.12	10.10	-0.91	0.28	0.23
	CATAM[4]	-2.2	46.7	4.67	1.55	32.5	$23.4^{84.07}$	$0.90^{2.77}$	26.00	66.81	21.23	-0.47	0.34	0.23
	CATAM[5]	+2.2	59.1	5.91	1.52	37.1	$27.3^{73.58}$	$1.05^{2.83}$	26.00	74.28	26.86	+0.37	0.46	0.34
	CATAM[6]	-2.8	62.0	6.20	1.75	38.1	$28.6^{75.65}$	$1.10^{2.89}$	26.00	71.77	22.14	-0.45	0.52	0.37

Appendix 5A: Duplicate Readings for Proximate and Mineral Compositions of Sweet Cassava root tubers and cocoyam Corms (% DM basis)

Nutrients	whole cassava unpeeled	whole cocoyam unpeeled	peeled cassava (tissue only)	peeled cocoyam (tissue only)	cassava peels only	cocoyam peels only	Corn (TZB)
Moisture Content	56.60	74.91	55.43	66.45	75.18	76.10	7.79
	56.90	75.60	56.37	67.55	75.22	76.40	5.18
Dry Matter	43.10	24.95	43.90	32.70	23.74	23.50	94.19
	43.40	24.45	44.30	33.30	24.86	24.00	92.03
Ash	2.64	5.02	2.66	2.44	5.56	4.33	1.81
	2.74	3.48	1.94	4.42	5.94	7.05	1.55
Organic Matter	97.36	94.98	97.34	95.58	94.44	92.95	93.57
	97.26	96.52	98.06	97.56	94.06	95.67	94.75
Crude Protein	5.00	6.29	3.72	5.26	7.00	6.13	12.28
	5.50	9.56	2.94	8.14	7.44	8.25	11.88
Crude Lipid	0.89	0.59	0.64	0.35	1.88	0.72	2.66
	0.57	0.51	0.42	0.37	0.92	0.66	3.64
Crude Fibre	3.85	3.89	2.17	2.16	9.98	7.19	2.60
	4.07	3.69	2.10	2.20	10.13	7.40	2.63
Minerals							
Sodium	0.051	0.059	0.070	0.059	0.091	0.071	0.002
	0.050	0.061	0.071	0.062	0.090	0.070	0.002
Potassium	0.431	0.953	0.879	0.681	1.501	1.202	0.261
	0.430	0.951	0.880	0.688	1.502	1.200	0.260
Calcium	0.101	0.070	0.561	0.051	0.630	0.170	0.011
	0.102	0.072	0.560	0.052	0.633	0.170	0.010
Magnesium	0.091	0.131	0.091	0.121	0.131	0.201	0.092
	0.091	0.132	0.091	0.121	0.132	0.200	0.091
Phosphorus	0.020	0.151	0.032	0.120	0.050	0.150	0.183
	0.020	0.153	0.031	0.120	0.050	0.151	0.182
Zinc (ppm)	52.003	80.000	20.000	65.003	115.002	115.001	32.501
	52.001	80.000	20.000	65.001	115.003	115.000	32.503
Iron (ppm)	80.000	200.001	20.000	60.000	320.002	300.003	25.001
	80.000	200.001	20.000	60.000	320.001	300.001	25.001

Nitrogen-free-extract, Carbohydrate by Difference and Calorific values were not done by direct methods but calculated (using average values) as described on page 62 of this Thesis. Hence, there are no values for them in the Appendix.

Appendix 5B: Duplicate Readings for Proximate and Mineral Compositions of Parkia and Tamarindus Seeds (% DM basis)

Nutrients	Parkia whole seeds	Tamarindus whole seed	Parkia seed nuts (kernels)	Tamarindus seed nuts (kernels)	Parkia Lab. Fermented	Parkia Market Fermented	Tamarindus Fermented seed nuts	seed testa (soaked)	seed testa (boiled)
Moisture Content	7.50	11.00	12.00	25.80	6.50	11.50	34.60	17.00	37.00
	7.20	10.96	13.00	25.50	6.00	13.53	35.00	16.50	36.60
Dry Matter	92.80	89.04	88.00	74.20	94.00	88.50	65.40	83.00	63.40
	92.50	89.00	87.00	74.50	94.50	86.50	65.00	85.50	63.00
Ash	4.37	2.36	2.13	1.63	1.72	5.00	1.47	3.39	2.26
	4.29	2.34	2.09	1.61	1.76	5.22	1.45	3.35	2.24
Organic Matter	95.63	97.64	97.87	98.37	98.28	94.69	98.53	96.61	97.74
	95.71	97.66	97.91	98.39	98.24	95.09	98.55	96.65	97.76
Crude Protein	30.14	15.09	42.68	19.89	46.93	32.58	20.99	10.38	10.19
	26.26	17.03	48.04	18.42	45.07	34.30	18.09	8.34	10.21
Crude Lipid	15.77	3.22	27.17	3.51	30.33	27.20	2.54	1.39	0.39
	15.75	3.30	28.31	3.56	30.31	27.38	2.40	1.44	0.37
Crude Fibre	14.24	3.16	4.67	2.16	8.86	8.88	2.34	37.14	24.85
	14.18	3.20	4.71	2.15	5.63	8.82	2.60	35.65	24.56
Minerals									
Sodium	0.012	0.004	0.021	0.021	0.021	0.020	0.020	0.501	0.021
	0.011	0.004	0.020	0.020	0.022	0.021	0.020	0.497	0.020
Potassium	1.001	0.020	0.182	0.089	0.221	0.503	0.121	0.057	0.059
	1.001	1.020	0.183	0.088	0.222	0.500	0.123	0.056	0.061
Calcium	0.221	0.101	0.112	0.201	0.150	0.158	0.251	0.069	0.060
	0.223	0.100	0.109	0.203	0.151	0.161	0.250	0.072	0.061
Magnesium	0.338	0.103	0.190	0.131	0.188	0.210	0.141	0.301	0.302
	0.339	0.100	0.190	0.131	0.181	0.212	0.140	0.304	0.301
Phosphorus	0.250	0.210	0.292	0.230	0.390	0.380	0.273	0.011	0.011
	0.270	0.220	0.311	0.231	0.390	0.400	0.271	0.012	0.013
Zinc (ppm)	80.000	87.450	95.600	39.971	105.002	70.002	47.501	32.270	16.623
	80.000	87.550	95.700	39.931	105.001	70.001	47.503	32.250	16.621
Iron (ppm)	74.920	74.530	100.090	101.551	200.000	575.003	150.000	55.645	95.555
	75.110	75.471	100.050	101.552	200.001	575.000	150.000	55.655	95.545

Appendix 5C: Duplicate Readings For Amino Acid Composition of Sweet Cassava root tubers and Cocoyam Corms (% DM basis)

Amino Acid	Whole Cassava unpeeled	Whole Cocoyam unpeeled	Peeled Cassava (tissue only)	Peeled Cocoyam (tissue only)	Cassava Peels only	Cocoyam Peels only	Corn (TZB)
Lysine	0.17	0.60	0.13	0.52	0.33	0.48	0.43
	0.20	0.64	0.15	0.56	0.37	0.50	0.47
Histidine	0.10	0.33	0.07	0.30	0.09	0.30	0.60
	0.10	0.35	0.07	0.30	0.11	0.32	0.58
Arginine	1.02	1.01	0.59	0.85	1.09	0.74	0.76
	1.20	1.05	0.41	0.89	2.73	0.70	0.70
Aspartic acid	0.26	1.20	0.15	1.20	0.47	1.20	1.60
	0.20	1.60	0.17	1.28	0.45	1.26	1.62
Threonine	0.08	0.48	0.06	0.44	0.17	0.42	0.66
	0.10	0.50	0.06	0.48	0.15	0.46	0.86
Serine	0.10	0.60	0.07	0.58	0.21	0.55	0.89
	0.24	0.64	0.09	0.60	0.23	0.59	1.05
Glutamic acid	0.57	1.02	0.47	1.01	0.95	1.02	4.02
	0.67	1.22	0.45	0.97	0.99	1.06	4.22
Proline	0.08	0.33	0.06	0.36	0.16	0.35	1.63
	0.10	0.39	0.04	0.34	0.16	0.37	2.09
Glycine	0.10	0.56	0.09	0.50	0.17	0.51	0.71
	0.10	0.58	0.07	0.54	0.19	0.55	0.77
Alanine	0.17	0.49	0.13	0.49	0.27	0.47	1.79
	0.13	0.49	0.13	0.47	0.23	0.49	1.99
Cystine	n.d	0.20	n.d*	0.20	n.d	0.22	0.29
	n.d	0.22	n.d	0.20	n.d	0.24	0.25
Valine	0.10	0.52	0.08	0.50	0.20	0.50	1.04
	0.12	0.54	0.08	0.54	0.20	0.50	1.20
Methionine	0.04	0.10	0.02	0.11	0.07	0.10	0.33
	0.06	0.10	0.04	0.11	0.05	0.10	0.35
Isoleucine	0.11	0.39	0.07	0.37	0.18	0.32	1.00
	0.11	0.37	0.05	0.41	0.18	0.38	1.00
Leucine	0.15	0.86	0.10	0.87	0.26	0.80	2.55
	0.17	0.88	0.10	0.88	0.28	0.82	2.95
Tyrosine	0.10	0.45	0.07	0.42	0.17	0.40	0.80
	0.10	0.47	0.05	0.44	0.20	0.46	1.00
Phenylalanine	0.10	0.54	0.05	0.51	0.16	0.47	1.20
	0.09	0.50	0.07	0.47	0.18	0.49	1.26

*n.d = not detected.

Appendix 5D: Duplicate Reading for Amino Acid Compositions of Parkia and Tamarindus Seeds (% DM basis)

Amino Acid	Parkia whole seeds	Tamarindus whole seeds	Parkia seed nuts (kernel)	Tamarindus seed nuts (kernels)	Parkia Lab. Fermented	Parkia Market Fermented	Tamarindus Fermented seedhuts	Parkia Seed testa (Soaked)	Tamarindus seed testa (boiled)	Casein
Lysine	2.59	1.37	4.02	1.89	4.09	3.05	1.97	0.90	0.33	0.35
	2.57	1.33	4.06	1.85	4.05	3.25	1.95	0.70	0.35	0.33
Histidine	1.14	0.70	1.91	0.71	1.94	1.30	0.73	0.40	0.90	2.68
	1.18	1.72	1.94	0.73	1.96	1.50	0.75	0.44	0.94	2.60
Arginine	2.02	1.50	3.29	1.49	3.01	1.82	1.40	0.68	0.51	3.30
	2.06	1.52	3.25	1.47	3.21	1.86	1.42	0.64	0.55	3.36
Aspartic Acid	3.30	1.96	4.56	2.74	4.50	3.10	2.60	0.95	0.80	6.64
	3.32	1.94	4.52	2.76	4.56	3.70	2.80	0.95	0.78	6.84
Threonine	1.24	0.50	1.87	0.80	1.72	1.19	0.79	0.44	0.20	3.99
	1.28	0.70	1.89	0.84	1.76	1.17	0.77	0.40	0.24	4.01
Serine	1.79	1.03	2.69	1.25	2.43	1.10	1.22	0.59	0.51	5.05
	1.78	1.09	2.65	1.45	2.49	1.70	1.42	0.57	0.59	5.45
Glutamic Acid	5.13	2.96	7.33	4.00	7.41	6.09	4.00	1.49	1.09	18.64
	1.15	2.92	7.39	4.22	7.43	6.05	4.02	0.47	1.07	22.60
Proline	1.60	0.67	2.29	0.91	2.10	1.48	0.90	0.41	1.18	10.09
	1.66	0.63	2.25	0.95	2.18	1.50	0.94	0.45	0.20	10.05
Glycine	1.49	1.50	2.20	1.14	2.05	1.60	1.16	0.82	1.58	1.78
	1.47	1.58	2.20	1.30	2.25	1.62	1.22	0.84	1.60	1.70
Alanine	1.74	0.78	2.59	1.03	2.52	1.79	1.07	0.59	0.32	2.98
	1.70	0.80	2.57	1.05	2.56	1.77	1.09	0.61	0.34	2.78
Cystine	2.20	0.38	1.07	0.40	0.89	0.66	0.40	0.13	0.11	0.34
	2.80	0.40	1.03	0.44	0.85	0.60	0.48	0.15	0.13	0.32
Valine	1.52	0.71	2.60	1.10	2.43	1.88	1.08	0.48	0.19	6.20
	1.50	0.75	0.56	1.10	2.47	1.92	1.10	0.52	0.21	6.22
Methionine	1.00	0.18	0.29	0.15	0.42	0.32	0.29	1.10	0.06	2.50
	1.00	0.20	0.27	0.35	0.44	0.36	0.27	0.10	0.04	2.70
Isoleucine	1.40	0.82	2.25	1.19	2.20	1.70	1.20	0.40	0.20	4.70
	1.50	0.86	2.29	1.17	2.30	1.74	1.28	0.44	0.22	4.92
Leucine	2.50	1.40	3.74	1.86	3.70	2.80	1.96	0.80	0.33	8.43
	2.54	1.30	3.78	1.84	3.72	2.82	1.94	0.60	0.35	8.89
Tyrosine	1.07	1.01	2.03	1.07	1.87	1.70	1.13	0.37	0.82	5.20
	1.09	1.01	2.05	1.27	1.91	1.78	1.15	0.39	0.86	5.46
Phenylalanine	1.68	0.83	2.70	1.21	2.52	1.90	1.17	0.40	0.27	4.90
	1.64	0.87	2.50	1.27	2.57	1.94	1.19	0.46	0.23	4.94