LEAST-COST RATIONS FOR BROILERS - A LINEAR PROGRAMMING APPROACH

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TO MY GRANDMOTHER
MADAM RUTH OMIRETI ABIDOGUN

Abstract

It has been established that Nigeria has a food problem especially where protein intake is concerned. The poultry industry has been identified as the quickest means of expanding protein supply and lowering its cost within the short run (10-12 weeks for broilers). However, feeds account for 65-75 percent of the total costs of production. Moreover, the numerous problems facing the feed industry coupled with the poor quality of feeds produced have greatly limited the profitability and rapid expansion of the industry. The linear programming (L.P.) tool was utilized to formulate least-cost diets which made use of locally available ingredients. The scarcity and rising costs of the grains (maize and guinea-corn) which provide over 60 percent by weight of broiler feeds prompted the use of cassava flour as an energy providing substitute. Feeding trials were carried out to test the efficiency of the least-cost diets.

The objectives of the study are

(1) To use L.P. tool to formulate different least-cost rations which meet specific nutritional specifications for broilers, using readily available feed ingredients. Cassava and soya-bean are being tested as energy and protein providing substitutes respectively.

(2) To compare the least-cost formulated diets with the diets used by some commercial farms.

(3) To find the optimum killing age/weight.

(4) To find the rate of substitution of cassava flour for maize and guinea-corn in the ration for broilers.

(5) To determine the economics of using different levels of cassava flour in the rations for broilers.

Experimental results showed that starter diets with 24 percent protein and 5 percent fibre level were better than those with 26 percent protein and 3 percent fibre levels. The computerised starter and finisher diets tested were cheaper and were found to perform better than the commercial diets.

For the cassava based diets, analysis of the experimental results showed significant ($P < 0.01$, $P < 0.05$) differences in Feed Conversion Efficiency (F.C.E.) in both starter and finisher diets in which guinea-corn and maize were replaced. For weight gain, significant ($P < 0.01$) differences were found only in starter and finisher diets in which cassava replaced maize. For feed intake, significant differences ($P < 0.01$) occurred only in starter diets in which cassava replaced maize. The diets that caused significant differences were those in which the cassava contents were very high (25-40 percent) and they performed poorest. Even though growth is suppressed due to reduced feed intake caused by the powdery nature of the feeds, it is pertinent to note that diets with 40 percent cassava are still highly tolerable to the birds. Analysis of the weight response as cassava level increases showed that the decrease in weight gain was more rapid when cassava was being substituted for by maize rather than by guinea-corn. This could be attributed to the availability of nutrients or the amino-acid balance of the guinea-corn based diets. Carcass qualities of the birds were not taken into consideration because they are not highly rated in this society.

The diets were further investigated to see how the nutrients contents and energy-based ingredients influenced performance, using the multiple linear regression model. The square root and quadratic functions were fitted but the quadratic forms gave the lead equations using the laid down criteria. Feed, protein, energy and the amino-acids intakes proved to be significant explanatory variables for the live-weight gain in the birds. Marginal Analysis was performed on some selected functions. The elasticity of production for energy and protein showed increasing returns to scale in the starter and finisher diets at the mean value of inputs. As higher levels of inputs are used, diminishing returns is likely to set in. The elasticity of substitution exhibits a unitary one also at the mean value of inputs. A percentage increase in the energy content of the feed results in an equal percentage decrease in the protein level of the diet. The extent of substitution is limited by the requirement of the birds. Optimum quantities of the energy-based ingredients to produce the optimum broiler weight gain were determined. Production surfaces, isoquants and isoclines were produced for selected functions of the energy-based ingredients. The rate of substitution between guinea-corn/cassava and maize/cassava were found to be declining with increasing level of output as more of cassava and less of maize or guinea-corn are used.

Estimates of revenue over feed costs for the various diets were computed. It was discovered that non-significant differences between diet without cassava was not synonymous with equal revenue yielding diets. In general, the computerised diets without cassava gave higher revenue than the commercial diets. For the diets in which cassava replaced the grains, the revenue accruing to the farmer decreased as the percentage cassava content increased. The revenue from guinea-corn diets were however higher than in the maize diets. Diets with 10 percent cassava had higher or equal revenue with the commercial diets. Diets with higher cassava levels were costlier because cassava is costlier than the grains. It is however envisaged that prices of cassava may fall in the near future because of increases in production. Revenue from the diets was therefore obtained using var.ing costs of diets as cassava price varies. When cassava was made to assume the same price with guinea-corn, all the computerised diets except that with 30 percent cassava level had higher revenues than the commercial diets. The revenue increased as the cassava prices were reduced but the diets with 30 percent cassava gave the lowest revenue all the time. Optimum killing age determined suggested that broilers be sold at eleven weeks for most of the diets except those in which five and 10 percent cassava replaced guinea-corn.

The implications of this study are that efforts to improve returns to poultry farmers must be focussed on the cost and quality of feeds.

Particular attention must be paid to cheap sources of protein, carbohydrate and oils. There is a very high potential for the use of cassava if its adoption becomes a reality in the future.

Further investigations are necessary in testing the least-cost diets with the existing various breeds of broilers. Comparison can also be made of the use of soyabean and groundnut cake as a protein providing ingredient in broiler diets.

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CERTIFICATION BY SUPERVISORS

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CHAPTER ONE

INTRODUCTION

The Nigerian government, in order to reduce the importation of poultry products and to increase the amount of dietary protein available, initiated a rapid agricultural development programme in the 1962-68 plan. Steps taken included the production of breeding flocks, the establishment of hatcheries and feed depots in major towns as service centres in the country. Greater efforts were made in subsequent National Plans and a large number of entrepreneurs ventured into poultry production. Unfortunately, most producers went out of business due to low margin of profit and, in most cases, losses sustained This was due, among other factors, to the fact that feed costs were very high and inspite of the high costs, the feed were of poor quality.

1.1 The Problem

1.1.1 Deficiency in Protein Intake

It is an established fact that the protein intake of the average Nigerian either from plant or animal origin is inadequate. For instance, the FAO surveys 19/ showed that about 90 percent of the protein in the diet of the average Nigerian is derived from vegetables, pulses and nuts, thus leaving only 10 percent to be supplied by animals. In fact, the supply of vegetable protein is adequate only in the Northern part of the country and the supply of animal protein is also higher there than in the Southern parts.

Table 1.1 shows the available average calories and protein supply per capita in the former 12 States of Nigeria for 1968/69.

TABLE 1.1: Available average calories and protein supply per capita in the 12 states of Nigeria 1968/69

STATES	PER CAPITA SUPPLY OF		
	Protein per day (grains)	Calorie/day (Kcals.)	Protein/Calorie (Percentage)
Federal Nigeria	58.78	2,198	10.7
Benue Plateau	82.31	3,961	8.3
East-Central	66.62	3,091	8.6
Kano	62.14	2,377	10.5
Kwara	56.87	2,236	9.7
Lagos	38.14	2,237	6.8
Mid-West	77.14	2,881	10.7
North-Central	56.66	2,037	11.1
North-Eastern	54.46	1,892	11.5
North-Western	50.41	1,751	11.5
Rivers	45.71	2,444	7.5
South-Eastern	56.99	2,887	7.9
Western	53.43	2,950	7.2

Source: Compiled from food balance sheet tables (9-22) of Olayide, S. O., et al. 59/.

These figures do not measure up to the FAO recommendations of 2,500 kilocalories of energy and 65 grams of protein per day except for Mid-West, Benue-Plateau and East-Central States which have 77 grams, 82 gms. and 67 grams of protein per day and 2,881, 3,961, 3,091 kilocalories of energy per day respectively. Two other Southern States, Western and South-Eastern, have energy supplies greater than the recommended figure but their protein intakes are below standard. The protein/calorie percentage figures are higher in the Northern States than in the Southern States.

The FAO estimated per caput consumption of all types of meat (excluding offals) to be 9.2 kg. per year, 7.1 kg. per year and 5.2 kg. per year in the North, West and East respectively. This is very small compared with the FAO recommendations of 65 grams of protein per day out of which 35 grms. should be of animal origin. The FAO 1969[18/] report also show protein shortage in the diet of the average Nigerian. It observed that the low average intake of animal products could be due to either their non-availability or the fact that they are too costly for certain income groups. The workings of economic forces show that it is due to both. If demand exceeds supply, denoting unavailabili price rises so high that some income groups cannot afford it.

1.1.2: Expansion of Protein Supply

The high price of animal products prevents the low income earners from using the sources of animal protein which otherwise should have been made available cheaply to them to improve their nutrition.

The quickest means of increasing animal protein supply within the short run is through rapid expansion of the poultry industry. The poultry industry is characterised by a short economic cycle (10-12 weeks for broilers) and should be relied upon to provide a significant proportion of the animal protein needs of the rapidly growing population. The industry requires a package of cheap and best quality feeds, best breed of birds with good intensive management practices in a commercial set up. Unfortunately, poultry production in Nigeria is characterised by high costs, small profit margins and the need for adequate financing.[60/]

Cattle, sheep and goats are important in the Northern parts of the country where extensive natural grassland areas are available. In the South, extensive arable pasture no longer exists because of high population pressure on land and the dense vegetation. The South would therefore have to rely mostly on poultry and piggery industries for most of their protein requirements since pigs and poultry convert grain seeds and waste products unfit for human consumption into meat.[57/]

Within poultry production however, returns to capital come quicker from broiler production than egg production because broiler production is characterised by lower capital turnover than in egg production, (38, 41, 60) and in 10-12 weeks thousands of broilers can be produced. However, since feed accounts for up to 65 percent of the costs of production, the cost and quality of feeds have greatly limited the profitability of and thus the rapid expansion of the broiler enterprise.

1.1.3: Feed Costs and Quality

The most important factor determining profit levels in intensive livestock enterprises is the cost of feeds. Ikpi [32] gave the percentage contribution of feed costs in broiler production as 64.37. Heady [27] and Blagburn [10] gave it as lying between 65-75 percent.

Feed prices keep rising as the demand for feed increases. Oyenuga [62] attributed the rise in the prices of feed to steep rise in the prices of the basic feed ingredients such as maize, groundnut cake and fish meal which rose by 114, 100 and 355 percent respectively between 1969 and 1974.

Table 1.2 below shows the price trend of livestock feeds in Ibadan (Oyo State) from 1972-78. From this table, prices of the various kinds of livestock feeds increased in the range of 111 pereent to 164 percent within the seven year period.

Fatteners and weaners mash increase respectively by about 111 and 126 percent whilst pig breeders mash increased by 119 percent within the seven year period. Growers mash increased by 130 percent . Layers mash by about 144 percent, broiler finisher by about 134 percent and broiler starter by about 155 percent. The highest increase was obtained in the price of chicks mash which rose by about 164 percent.

It would appear therefore that the most reasonable cause of action is a combination of measures designed to reduce the cost of feeds and improve the quality of diets such that a high level of animal performance and feed efficiency could be attained.

The main economic problem is concerned with the relation between total feed input and meat output. It is characteristic of broilers like all other

TABLE 1.2: Price (N/Ton) of livestock feeds in Ibadan, Oyo State, Nigeria, 1972-1978

KINDS OF FEED	YEARS							% Price Increase
	1972	1973	1974	1975	1976	1977	1978	
Chicks mash	109	152	156	200	220	248	288	164.2
Growers mash	100	130	132	160	180	212	230	130.0
Layers mash	104	148	152	167	210	228	254	125.1
Breeders mash	118	152	166	196	n.a.	n.q.	n.a.	
Broiler Starter	132	152	166	198	294	308	336	154.6
Broiler Finisher	130	148	162	196	288	298	304	133.9
Piggery Creep	148	137	198	198	n.a.	n.a.	n.a.	
Weaners mash	109	119	138	176	202	226	246	125.7
Fatteners mash	108	115	166	166	188	218	228	111.1
Breeders mash	108	113	144	144	162	214	236	118.5

Source: Pfizer Products Limited.

n.a. = not available.

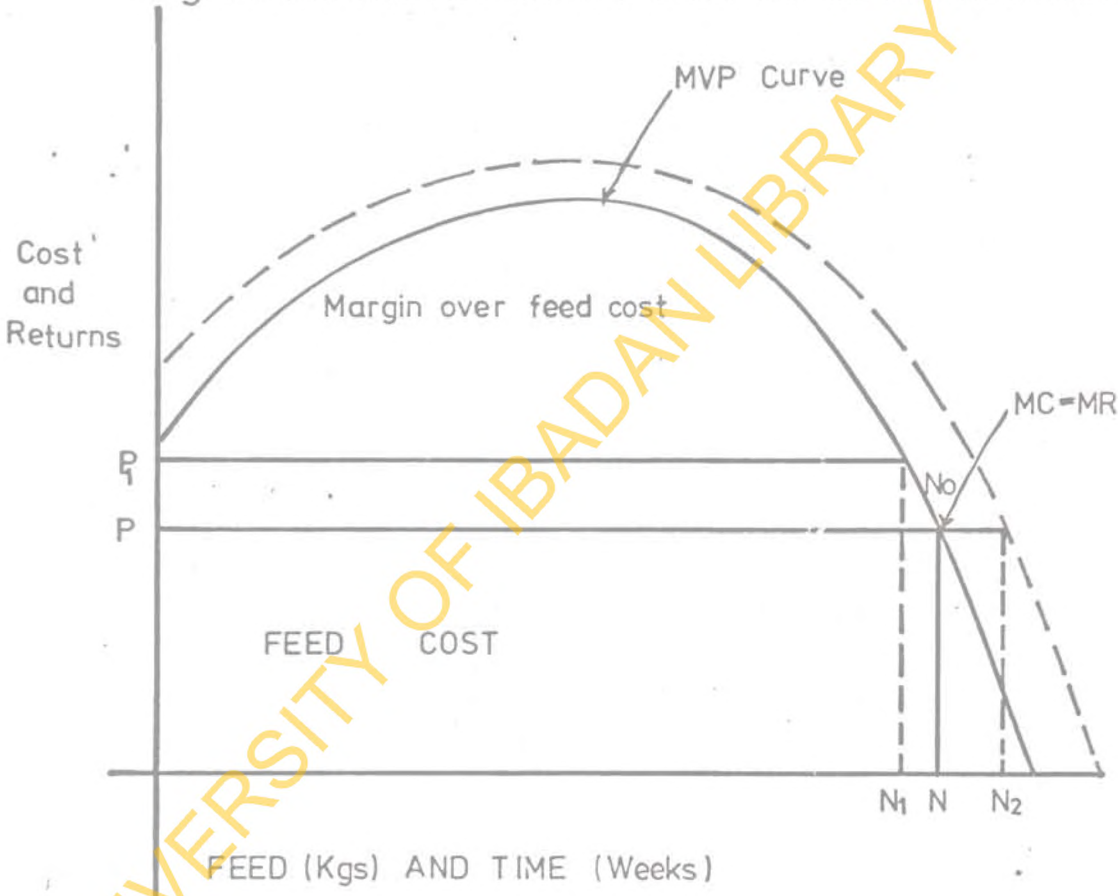
growing stock that their efficiency as feed converters declines with age. It is most profitable to sell off the birds or kill them at the point where the margin over total feed costs per bird is at its maximum. This is the point where the value of extra meat produced with continuous feeding is equal to the extra cost of feed.

Figure 1.1 below illustrates the point further. The figure shows the value of extra meat production resulting from every additional gram of feed, assuming the prices of poultry meat and feed to be constant. The MVP curve shows the diminishing marginal return relationship between feed input and meat output and the feed cost line is horizontal showing a constant price.

These two curves intersect at point No., where MC = MR and here the net returns to feed are maximised and can be converted to an optimum killing age or weight (ON).

If, for example, the price of feed increases, the optimum killing age will be shortened to the point where the dotted line intersects the MVP curve (ON). Similarly if feed is more efficiently converted into meat, or if the price of poultry meat rises, the MVP moves up to the dotted curve and this will increase the optimum killing age to the new point of intersection between the two curves (ON_2). Efficiency of feed conversion obviously depends upon the quality of feed, poultry management, and genetic ability of the birds to convert feed into meat. Since feed is the major item of cost, it is evident that an improved ratio (kg. of feed required to produce 1 kg. of poultry meat) will result in a significant reduction in the costs of production. An increase in feed efficiency obviously has greater impact in reducing the cost per kilogr

Fig. 1·1: ECONOMIC INPUT/OUTPUT RELATIONSHIPS



MVP Marginal Value Product
MC Marginal Cost
MR Marginal Revenue

Optimum point of production is where MC=MR liveweight when the price of feed is high.

1.2: The Need for This Study

The need for this study arose, therefore, from the desire to expand poultry production to improve the nutritional status of the average Nigerian by making poultry production possible at low costs.

Some of the possible solutions to the expansion of the poultry industry lie in reducing the unit cost of production through efficient ration formulation. But since feed costs represent a significant proportion of the total cost of production, much attention should be paid to producing good quality feeds at the lowest prices possible.

Reduction in feed costs could be accomplished by making use of locally available ingredients, substituting some ingredients for others in response to changing price structure, achieving management and technical efficiency in feed mills through capacity utilisation and workable procurement and distribution arrangements for ingredients and feeds, respectively.

In particular, the scarcity and the rising costs of maize which provides over 60 percent by weight of broiler feeds calls for a search for other energy providing substitutes. Accordingly, the exploration of the possibility of substituting cassava for maize as the major sources of energy in broiler ration could be regarded as a worthwhile exercise. Moreso when it is realised that the production of guinea-corn is not yet well organised and the competition between human beings, livestock, textile and starch industries for maize makes the locally produced maize so scarce and costly. Cassava is being considered because a lot of work has been done by research institutions both in its production and use in livestock feeds. The economic aspect has however, been neglected.

1.3: Objectives of the Study

The objectives of this study are:

1) To use Linear Programming (LP) tool to formulate different least cost rations which meet specific nutritional specifications for broilers, using readily available feed ingredients in Nigeria. Soyabean and cassava are being tested as protein and energy substitutes, respectively.

2) To compare the least-cost formulated/computerised diets with the diets used by some commercial farms by feeding the different diets to broilers.

3) To find the optimum [illegible].

4) To find the rate of substitution of cassava flour for maize and guinea-corn in the rations for broilers.

5) To determine the economics of using different levels of cassava flour in the rations of broilers.

1.4: Plan of Thesis

The second chapter traces the historical development of computer formulated diets for livestock. The relationship between them and the present study are highlighted. The tool or technique used is thoroughly examined.

The model for least-cost ration formulation is stated with the problems involved.

The third chapter discusses the least-cost ration compositions employed in the study. It shows also how the nutrient requirements are met to ensure a balanced diet.

Chapter four discusses cassava as a component of animal feed, focussing in particular on the advantages and disadvantages of its use. The results of the substitution of cassava for maize and guinea-corn in the L.P. model are also presented here.

In chapter five, the model used for the feeding trials is discussed including the experimental design and setting. The management, diseases and general condition of the experimental broilers are discussed thus revealing the limitations of the study. Performance comparisons of all the experimental diets are made.

Chapter six presents the major results of the study. Empirical estimation of parameters affecting broiler diets dominated the chapter. Nutrient effects either singly or in combination with each other and the extent of dependence on amino-acids for growth are examined. An economic analysis is performed for the diets and Linear Programming is compared with marginal analysis as optimum decision criteria.

Chapter seven gives the summary of major findings, general conclusion and the policy recommendations.

CHAPTER TWO

LINEAR PROGRAMMING AND FEED COMPOUNDING - A THEORETICAL REVIEW

2.1: Previous Works in Computer-formulated Poultry Diets

A lot of work has been done in the field of Linear Programming formulation of poultry feeds.

Anwar [2/] used L.P. tool to compute least-cost chick starter ration according to the ratio between protein quality value and energy content. He incorporated Gross Protein Value Units (G.P.V.Us) into the computer-formulated least-cost ration so as to make optimal use of a most meaningful measure of protein quality. The ingredients used constituted 95 percent of the ration and the remaining five percent was contributed by the different feed additives. He supplemented the protein rich feedstuffs with lysine and methionine which are the most limiting amino-acids. The protein-rich feedstuffs which were supplemented were considered as different ingredients having higher prices, since the GPVs increased more than for the unsupplemented ones. With soyabean as the protein source, he found lysine to be ineffective whilst supplementation with methionine was economical, both in the reduction of the cost of the ration and the increase in weight gains. Anwar also emphasized the measure of the protein quality of the feed.

Gibson, et al.[25/] devoted their study to a detailed examination of the methods and procedure involved in the use of L.P. and an electronic computer to determine several types of least-cost poultry rations including chick starte turkey starter, layer and broiler rations. They also examined the effects of changing feed ingredient prices on the least-cost rations. They suggested that the results of an L.P. analysis are only as reliable as the input data which are used.

This study did not only confirm the usefulness of interdisciplinary cooperation in agriculture but the results also have important implications for both poultry nutrition research and their applications to commercial feedmill operations.
however, the only shortcoming in the study is the failure to recognise that least-cost rations are not necessarily the most economic in terms of profitability. This could have been ascertained through feeding trials designed to test the birds' performance on and the levels of profit from the various least-cost rations.

Heady, Balloun and McAlexander [27] estimated and fitted broiler production functions and specified least-cost rations over two weight ranges. Growth isoquants indicating the possible combinations of two major feed ingredients (corn and soyabean) which result in a fixed gain level were predicted. They also determined the optimum level of feeding as well as the optimum market weight.

Flinn [23] estimated broiler production functions as well as response surfaces, using diets of varying protein levels. He performed carcass quality tests and determined various economic indices such as optimal slaughter weight, and least-cost feed rations. Least-cost feed rations were determined by finding least-cost input combinations that produce the optimal slaughter weight. He found that least-cost inputs however, depend solely on the ratio of input prices and the biological characteristics of the response surface. This study uses predetermined least-cost computerized rations in the feeding trials for the purposes of estimating such economic indices.

2.2: The Model for Least-Cost ration Formulation

Due to recent advances made in poultry nutrition research, it is becoming increasingly difficult to find the ration which is least-cost and at the same time, meets the recommended nutritional requirements.

A well balanced poultry ration may involve 20 to 30 nutrient requirements and many feed ingredients whose prices are constantly changing. Through long experience, it may be possible to determine the low-cost ration by trial and error methods, but this is costly and time-consuming and there is no guarantee that the selected ration is the least-cost one.

It has however, been demonstrated in various studies (2, 8, 13, 15, 22, 23, 25, 30, 31, 39, 57, 76) that the L.P. tool is a very powerful, rapid and efficient technique as far as formulating least-cost rations is concerned.

2.2.1: The Model

Suppose there are n ingredients X_1, X_2, ..., Xn such as maize, cassava, guinea-corn, blood meal, fish meal, groundnut cake, etc. available for formulating the ration, and their prices are C_1, C_2, ...Cn, then the problem reduces to minimising an objective function:

$$Z = \sum_{j=1}^{n} C_j X_j \quad \text{(eq. 2.1)}$$

where Z is the cost of the formulated ration

C_j is the net price per unit of activity (there are n different activities)

X_j is the level at which each activity is to be produced.

Usually, the rations have specified nutrient requirements or restrictions to meet the needs of the birds. If the percentage of nutrients such as metabolizable energy, protein, amino-acids, vitamins, fibre, calcium and phosphate is less or greater than the specified levels, it might reduce the quality of the ration. These restrictions constitute the constraints in L.P. model and they take the form of linear inequalities which means that the total requirements for any nutrient must be equal to or less than the total amount of that nutrient available in all the ingredients included in the ration.

The statement that the protein level in the ration must be less than or equal to the percentage protein in all the ingredients can be expressed as follows:

$$\text{Protein} \leq \sum_{j=1}^{n} a_{ij} x_j \quad \text{(eq. 2.2)}$$

Similarly for energy, the relationship can be expressed as follows.

$$\text{Energy,} \leq \sum_{j=1}^{n} b_{ij} x_j \quad \text{(eq. 2.3)}$$

For many nutrients that are involved, the problem can be stated as

$$\text{Minimize } Z = \sum_{j=1}^{n} C_j X_j \qquad \text{(eq. 2.1)}$$

Subject to

$$d_i \leq \sum_{j=1}^{n} a_{ij}\, x_j \qquad \text{(eq. 2.4)}$$

$$X_j > 0 \qquad \text{(eq. 2.5)}$$

Where,

d_i is the level of the i^{th} nutrient

a_{ij} or b_{ij} is per unit content of the i^{th} nutrient in the j^{th} ingredient

X_j is the level at which the j^{th} ingredient comes into the programme.

$X_j > 0$ specifies that there must be no negative activity, i.e., there must be no negative amount of ingredient.

Several modifications and/or refinements of the basic model could be constructed to make the solutions more nutritionally acceptable. For example, models could be structured to permit a specified level of an ingredient/nutrient, or a percentage range could be specified for certain nutrients. In symbolic terms, a model, which specifies exactly 0.01 percent of a given nutrient/tonne of ration can be expressed as follows:

$$0.01 = \sum_{j=1}^{n} a_{ij} x_j \qquad \text{(eq. 2.6)}$$

On the other hand, a model which specifies that a nutrient ingredient should be included in a given ration at the range of 2 - 5 percent per tonne could be represented as follows:

$$0.02 \leq \sum_{j=1}^{n} a_{ij}X_j \qquad \text{(eq. 2.7)}$$

$$0.05 \geq \sum_{j=1}^{n} a_{ij}X_j \qquad \text{(eq. 2.8)}$$

Equation (2.7) ensures that the ingredient/nutrient is included at a level not lower than 2 percent while equation (2.8) ensures that the nutrient/ ingredient is not included in the ration at a level higher than 5 percent All the symbols are as explained in the basic models.

2.2.2: <u>Problems of Diet Formulation</u>

Numerous problems face the farmer when formulating least-cost diets for livestock from time to time. There are two categories of farmers in livestock production namely (i) the feed compounder and (ii) the farmer who raises the livestock by feeding the computerised diets for meat, eggs or milk production. Problems of diet formulation can therefore be grouped into those from these two categories of farmers:

(a) <u>The feed compounder's problems</u>

(i) The most important problem of the feed compounder is that which concern the nutrient composition of feedstuffs. There is no doubt that there is considerable variability in the quality of feedstuffs from one batch to the other. This makes it compulsory that each batch of feedstuff be analysed. The available storage facilities even influence the nutrient availability of ingredients.

(ii) A second problem facing the compounder in setting restrictions for a balanced diet is that very little is known about the availability of the nutrients from the ingredients that are used to meet the specified requirements for nutrients. It is known that the animals do not make use of all the nutrients supplied to them. For instance, the amino-acid content of a feed is an important guide to quality but relatively little is known about the availability of individual amino acids in feed ingredients to the animals. Chemical tests that should overcome this uncertainty about technical coefficients are very expensive and time consuming.

(iii) Thirdly, random variations in the cost of ingredients depending on the magnitude of change, will affect the least-cost mix. The compounder therefore has to obtain a new least-cost composition for every change in cost outside the minimum and maximum range allowed by the Linear Program.

(iv) Fourthly, the compounder must decide on what his optimum goal should be. He can choose either cost minimisation or profit maximisation depending on his assets and facilities. For instance, cost minimisation is the aim of a farmer who has a small to medium size mill and depends very largely on the ability to handle small quantities of several diets. He must also have constant access to L.P. to scan the various recent available feed ingredients and their existing prices to meet each particular order. Whereas, a compounder selling feedstuffs to farmers and has ample storage, milling and mixing capacity to provide for the demands of all customers with respect to quantity and type of diet, is concerned with getting the maximum return on capital investment.

Lastly, the compounder must maintain the business by satisfying the demands of farmers. His greatest problem in this respect is that farmers generally do not buy in a perfectly competitive way. Also, for long term planning as to what his mill output should be, he depends very largely on the volume of sales which may not show the correct picture.

(b) The livestock Farmers' Problems

The livestock farmers' problem begins from the fact that he buys a cheaper mix which is supposed to meet stated nutrient standards but he does not know its interpretation in terms of their performances with the animals. His major problem is to maximise returns over food costs, especially in intensive livestock enterprises where food costs represent a large part of total costs.

Increasing or decreasing the nutrient contents of a diet does not mean that proportional changes will take place in the intake of the animal or that the increase or decrease in cost of the diet may be more than offset by the increase or decrease in performance. The farmer is thus mainly concerned about the influence of nutrient intake on animal performance. However, animal performance depends on a number of nutritional, genetic and environmental factors.

CHAPTER THREE

LEAST-COST RATION COMPOSITIONS EMPLOYED IN THE STUDY

3.1 The Basic Matrix

Table 3.1 shows the various feed ingredients that are possible components in a typical broiler starter/finisher ration, their prices per ton and their nutrient composition.

Nineteen available ingredients were considered in this study. They include maize, guinea-corn, and cassava which form the bulk of poultry rations and supply a high percentage of energy and reasonable amount of protein and amino-acids. They are readily available locally, but their supply is seasonal. The qualities and therefore their nutrient compositions also vary depending on the variety and efficiency of storage. Groundnut cake, blood meal, meat and bone scrap, fish meal and soyabean meal, supply the major part of protein and oil in the diet. Most of these have high percentages of essential amino acids – lysine and methionine. The minerals are to be supplied by Ad Vit. Most of the Nigerian feedstuffs have been evaluated for their nutrient compositions.[20,62,63, 64]. Differences in the estimates are attributable to varietal differences, local processing techniques and storage practices. However, the coefficients used in this study were obtained from series of analysis carried out by Pfizer Livestock Feed and the Faculties of Agriculture in some Nigerian Universities.

3.2: Restrictions in the Model*

There are three sets of restrictions: These are (a) the quantity of

*The basic matrix is used as reference point in this discussion.

TABLE 3.1: THE LINEAR PROGRAMMING BASIC MATRIX

				Guinea corn	G. nut Cake	Blood Meal	Brewers Grains	Bone Meal	Oyster shell	Fish Meal	Di-Calc. Phosph.	Salt	Meat & Bone Scrap	Palm Kernel Meal	Dried Yeast	Wheat Offals	Ad Vt	Syn. Methionine	Syn. Lysine	Maize	Soya bean	Cassava flour
	Average Producer	C_1		-220	-110	-70	-45	-60	-130	-600	-360	-224	- 56	- 75	-140	- 60	-1500	-1980	-4100	-265	-200	-320
	Pfyzer Prices	C_2		-200	-120	-80	-40	-60		-600	-1500	-220	- 52	- 70	-150	- 44	-1500	-2000	-4100	-250		
		B_1 BROILER STARTER	B_2 BROILER FINISHER																			
Equality	Weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Min.	Fibre	3.00	3.00																			
Max.	Fibre	5.00	5.00	2.90	3.00	0.72	16.8		[illegible]	0.36			1.96	10.34	1.84	11.64				1.29	5.21	1.42
NUTRIENT RESTRICTIONS																						
Min.	Protein	22	18	11.20	49.90	75.50	28.50			64.80			51.46	18.70	44.80	16.28		60.00	60.00	9.50	51.20	2.21
Max.	Protein	26	22	11.20	49.90	75.50	28.50			64.80			51.46	18.70	44.80	16.28		60.00	60.00	9.60	51.20	2.21
Min.	Energy (ME) kcals/kg.	2900	2800	3400	2853	2850	1648			2900			1914	1986	1850	2133				3360	2728	3624
Min.	Fat	4.5	2.5	3.40	16,40	0.97	7.20			7.50			10.42	6.74	1.23	4.00				3,83	7.94	0.92
Max.	Fat	7.5	4.5	3.40	16.40	0.97	7.20			7.50			10.42	6.74	1.23	4.00				3.83	7.94	0.92
Min.	Calcium	0.8	0.8	0.07	0.47	0.63	0.34	32.68	38.24	5.60	22.20		13.26	0.28	0.21	0.12				0.08	0.23	0.68
Max.	Calcium	1.5	1.2	0.07	0.47	0.63	0.34	32.68	38.24	5.60	22.20		13.26	0.28	0.21	0.12				0.08	0.23	0.68
Min.	Phosphorus	0.6	0.4	0.38	0.67	0.22	0.58	17.42	0.08	3.31	17.90		7.17	0.74	1.54	1.82				0.30	0.78	0.13
Max.	Phosphorus	0.8	0.6	0.38	0.67	0.22	0.58	17.42	0.08	3.31	17.90		7.17	0.74	1.54	1.82				0.30	0.78	0.13
Min.	Lysine	1.20	0.9	0.38	2.03	7.22	1.47			5.85			2.33	0.77	3.56	0.67			99.00	0.43	2.74	0.067
Max.	Lysine	1.30	1.30	0.38	2.03	7.22	1.47			5.85			2.33	0.77	3.56	0.67			99.00	0.43	2.74	0.067
Min.	Methionine	0.40	0.35	0.14	0.47	0.32	0.50			2.35			0.79	0.35	1.52	0.28		99.00		0.12	0.66	0.043
Max.	Methionine	0.60	0.50	0.14	0.47	0.32	0.50			2.35			0.79	0.35	1.52	0.28		99.00		0.12	0.66	0.043
Min.	Cystine	0.25	0.20	0.15	0.58	0.92	0.32			1.20				0.29	0.53	0.51				0.13	0.69	-
Max.	Cystine	0.45	0.35	0.15	0.58	0.92	0.32			1.20				0.29	0.53	0.51				0.13	0.69	-
Min.	Tryptophan	0.25	0.18	0.12	0.62	0.53	0.38			0.85				0.21	0,78					0.07	0.67	0.022
Max.	Tryptophan	0.35	0.25	0.12	0.62	0.53	0.38			0.85				0.21	0.78					0.07	0.67	0,022
INGREDIENT RESTRICTIONS																						
Max.	Guinea Corn	0.65	0.75	1.00																		
Max.	Groundnut Cake	0.30	0.30		1.00																	
Max.	Blood Meat	0.10	0.10			1.00																
Max.	Brewers Grains	0.05	0.08				1.00															
Max.	Bone Meal	0.03	0.035					1.00														
Max.	Oyster shell	0.03	0.03						1.00													
Max.	Fish Meal	0.10	0.05							1.00												
Max.	Di-Calc-Phosphate	0.03	0.03								1.00											
Equality	Salt	0.003	0.003									1.00										
Max.	Meat & Bone Scrap	0.075	0.075										1.00									
Max.	Palm Kernel Meal	0.15	0.15											1.00								
Max.	Dried Yeast	0.03	0.04												1.00							
Max.	Wheat offals	0.05	0.07													1.00						
Equality	Ad Vit	0.005	0.005														1.00					
Max	Maize	0.70	0.80																	1.00		
Max.	Soyabean	0.30	-																		1.00	
Max.	Cassava flour	0.30	0.40																			1.00

the total mix of ingredients which is the weight constraint; (b) the ingredient level specifications and (c) the nutrient requirement specification. These constraints are discussed fully below.

3.2.1: The weight Constraint

The weight constraint fixes the quantity of the mix within which the nutrient requirements and the ingredient specifications must be met. The model was constrained to produce exactly one tonne of the mix.

3.2.2: The Ingredient Constraints

Certain restrictions were placed on the levels of inclusion of availabl ingredients to conform with proved nutritional requirements and to take account of their availability and costs.

(a) Energy Based Ingredients: Guinea-corn and/or maize for instance should not exceed 70 percent of the mix because the birds should get limited energy supply from carbohydrate. Besides, there is high demand for these ingredients for human consumption and due to weather uncertainties, yields fluctuate and occasional shortages occur in supply. These render the grains very costly components of livestock feeds. Cassava is thus being included in the mix up to the 30 percent level in the starter and 40 percent level in the finisher rations. This is not to say that cassava is cheaper nor is it more readily available but it is being tested as a close substitute so that at least, producers have other choices when it is absolutely impossible to use the grains. Besides, the country is trying hard to preserve its foreign exchange and very soon may place restrictions on the importation of maize.

Also, the fact that maize is being imported at a cheaper price now is what makes cassava seem costly.

(b) Protein Based Ingredients: The model was structured to ensure a balance between protein supply from both plant and animal sources since this maintains a balance in the proportion of amino-acids contributed from vegetable and animal protein. This was accomplished in the model by setting the maximum level of groundnut cake at 30 percent whilst that of fish meal was at six percent. Blood meal was limited to 10 percent because of its low digestibility and the unbalanced nature of its supply of amino-acids. Palm kernel meal was limited to 15 percent because of its fibrous and gritty nature and its reported non-palatability for chickens at high levels. Meat and bone meal was limited to the low level of 0.75 percent because of its very unbalanced calcium-phosphorus ratio which could upset mineral balance if allowed to enter the mix at high levels.

(c) Mineral and Vitamin Based Ingredients: Allowance was made for the non-availability of phosphorus from grains and vegetable sources by insuring that the rations contain reasonable percentages of oyster shell or meat and bone scrap or bone meal to provide readily available calcium and phosphorus. Their maximum levels respectively are 3, 7.5 and 3.5 percent.

To improve the palatability of the diet and provide sufficient minerals and vitamins, the model specified that salt and Ad Vitamins should be 0.3 and 0.6 percent respectively for the starters. 0.5 percent level of Ad Vitamin was specified for the finishers.

Columns B_1 and B_2 of Table 3.1 show the restrictions specified in the basic matrix for the inclusions of various ingredients in the starters and finishers respectively.

3.2.3: Nutritional Restrictions

The nutrient content and intake of the rations determine the performance of intensive livestock enterprises.[5/]

(a) Energy: The energy level of the feed influences the rate of live-weight gains [33/]. The largest single dietary need of an animal is the energy source for physiological processes such as movement, respiration, absorption of nutrients, circulation, excretion, nervous system, temperature regulation and reproduction. The feed intake determines the rate of weight gain and this is dependent greatly on the energy content of the feed. The higher the energy content, the lesser the feed intake. Chicks were found to consume 50 percent more of low energy rations than high energy rations. But chicks fed high energy rations tend to have fatter carcasses and so require less total feed per unit of gain [11/]. The energy requirement cannot be given precisely. In general, however, broilers are usually fed high energy rations than pullets. Maximum growth rate has been found unattainable for energy level as low as 2,640 kcals./kg. of feed. [11/] Card and Neisheim [11/] gave a suitable range of energy to lie between 3,150 and 3,486 kcals/kg.

Table 3.2 below shows the various energy levels used in an experiment and their corresponding weights at the end of 11 weeks, the fat content of the carcass and the feed efficiency. Temperatures were observed during the period of the experiment and recordings show that maximum temperature during the coolest days were 69°F whilst the mean temperature was 55°F. Maximum temperature during the hottest days was 98°F while the mean was 86°F. These temperatures can be compared to our own environmental conditions.

TABLE 3.2: Performance of broiler rations containing higher levels of energy ranging from 1,760 kcals/kg – 3,160 kcals/kg.

Energy kcals./kg.	Av. weight in 11 weeks kgs.	Feed/chick kgs.	M.E. Intake kcals.	Fat in Carcass %	Feed/ Gain
3,159	1.47	4.37	13,805	26.6	2.92
2,342	1.48	4.44	12,519	23.2	2.97
2,528	1.52	4.92	12,432	21.1	3.23
2,211	1.47	5.10	11,286	18.1	3.49
1,896	1.46	5.46	10,344	15.1	3.74

Source: Table was abridged from "Poultry Production by Card and Nesheim (11)". Figures are converted to metric.

The above results in Table 3.2 confirm the conclusions that feeds with higher energy content have better feed conversion efficiency. Therefore, for the starter ration, a minimum energy level of 3,000 kcals. per kg. was specified.

For the finisher ration, minimum levels of 2,900 and 2,800 kcals./kg. were specified. Low energy levels have been specified because of existing high environmental temperatures. The mean temperature being about 88°F. It also helps to reduce the cost of the ration since the energy-providing ingredients are the most costly.

(b) Proteins: The protein needs of birds should be determined in terms of supplying adequate quantitative and proper balance of the essential amino-acids from the main protein constituents - fish meal, groundnut cake, soya-bean meal, blood meal, etc.

Typical broiler rations were said to contain 22-24 percent protein in the U.K. (Card and Neishim) Rao 33/ fed 18, 22 and 26 percent protein rations on pure bred broiler chicks from 0-10 weeks and finished them with 19 and 22 percent protein rations. He found body weights to increase with increase in protein level but the increases were not significantly different. He therefore recommended 22-24 percent protein in the starter ration and 19 percent protein in the finisher ration.

Flinn 23/ also fed rations with different protein levels on broiler birds and found no significant differences in the weight gains using 20 and 22 percent protein levels in the finisher rations.

For the purposes of this study, two levels of protein, 24 and 26 percent were specified for the starter rations whilst 20 and 22 percent were chosen for the finisher rations in accordance with the works done on protein in Nigeria. 5/ 42/ 43/ 54/

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For the purposes of this study, two levels of protein, 24 and 26 percent were specified for the starter rations whilst 20 and 22 percent were chosen for the finisher rations in accordance with the works done on protein in Nigeria. 5/ 42/ 43/ 54/

(c) Minerals: Calcium and phosphorus are the most important minerals in chicks nutrition. Not only must birds receive adequate amounts, but they must consume them in suitable proportions. The calcium phosphorus ratio should be within the range of 1.5:1. For both the starters and finishers, a minimum level of 1.5 and 1.2 were specified respectively. For phosphorus, the range was 0.4 – 0.8 percent.

Requirements are given in safety margins due to losses during processing and storage which result in variations in the nutrient contents of feed. Below is a table showing recommended levels of these minerals:

TABLE 3.3: Mineral requirement of chicks

Minerals	Starting Chicks and Broilers	Growing Chicks and Broilers
Calcium %	1.0	0.8
Phosphorus % (Available)	0.5	0.5

Source: Table was compiled from "Poultry Production" by Card and Neisheim (11) and "Poultry feeding and Management in the Tropics" by M. L. Scott (68)

Other minerals such as sodium, potassium, magnesium, chlorine, iodine, Iron, manganese, copper, molybdenium, zinc, selenium and cobalt are required only as constituents of vitamin B_{12}.

Birds cannot synthesise vitamin B_{12} using an inorganic source of cobalt. Calcium, phosphorus, sodium, chlorine and potassium are the major elements required in large quantities. Calcium is about one percent of the diet and the rest are needed in traces.

Lack of calcium, phosphorus and magnesium results in poor minerali-sation of the bone. The marked deformity of the skeleton may occur to give rickets. Phosphorus is essential in energy metabolism, it is a constituent of nucleic acids and activity of several enzyme systems. Calcium is important in blood clotting and muscle contraction. Deficiency in any of the minerals leads to poor growth and body dehydration.

(d) Amino-acids: The intake of nutrients such as the essential amino-acids - lysine, cystine, methionine, tryptophane, affect the growth rate of animals. Protein synthesis in the birds requires that all amino-acids needed to make up the protein be present in the body at nearly the same time. When an essential amino-acid is absent, no protein is synthesized at all. Carcasses of animals fed rations deficient in amino-acids usually contain more fat. Amir acids deficiency also results in poor feathering. The so called essential amino-acids are those which cannot be synthesized in the body and therefore have to be provided in the diet. Lysine, cystine, methionine and tryptophane are the critical amino-acids because they are difficult to supply in proper amounts from feed proteins. Cystine can however, be synthesized from methio-nine. Methionine supplementation of broiler diets at varying protein levels was found to improve the efficiency of feed conversion at all ages up to ten weeks but less markedly with advancing age.[26/] However, with female chicks, growth was stimulated to a limited extent only after four weeks. Female chicks are unable to convert methionine to cystine. Also with methionine supplementation, growth was depressed in rations with the widest energy: protein ratio. 26/

Methionine can replace some of the dietary choline. Tryptophane can be used to form Nicotinic acid. Tyrosine is needed for the synthesis of hormones such as adrenalin and thyroxin and also for the formation of melanic pigments.

Various authors have made their recommendations as regards the amino-acid requirement of chicks. Table 3.4 contains the recommendations of three authors on amino-acid requirements.

TABLE 3.4.1: Amino acid requirement of chicks

Amino-acids	Percentage of Protein	Starting Broilers % of diet	Percentage of Protein	Finishing Broilers % of Diet
Lysine	5	1.16	4	1.02
Methionine	2	0.47	2	0.41
Cystine	1.5	0.35	1.6	0.31
Tryptophan	1.0	0.23	1.0	0.21
Applicable Protein level		23.3	20.5	

Source: Table was abridged from "Poultry Production" by E. Card and Maldon C. Neisheim (11)

The tables which follow indicate similar recommendations as above.

TABLE 3.4.2: Amino-acid requirements

Amino-Acids	Percentage of Protein	Starter Protein in diet %			Finisher Protein in diet %		
		22.5	21.5	21.0	20.5	19.5	19.0
		Amino-acids as Percentage of the Diets					
Lysine	5	1.125	1.075	1.05	1.025	0.975	0.95
Methionine	2	0.45	0.43	0.42	0.41	0.39	0.38
Cystine	1.6	0.36	0.345	0.335	0.328	0.31	0.305
Tryptophan	1.0	0.225	0.215	0.21	0.205	0.195	0.19

Source: Table was abridged from "Nutrient requirement of chickens around the World" by M. L. Scott (69)

TABLE 3.4.3: Amino-acid requirements of chickens

Amino-Acid	BROILERS 0 - 6 weeks	6 - 9 weeks
Lysine (%)	1.25	1.10
Methionine (%)	0.86	0.75
Or		
Methionine (%)+	0.46	0.40
Cystine (%)	0.40	0.35
Tryptophan	0.23	0.20

Source: Table was abridged from Table 1 of pp. 203 in "Poultry Feeding and Management in the Tropics" by M.L. Scott in "Animal Production in the Tropics" edited by Loosli, Oyenuga and Babatunde.

From the above recommendations, a range of 1.25 - 1.85 percent was stated for lysine, 0.5 - 1.0 percent for methionine, 0.3 - 0.4 percent for tryptophan for the starter rations. For the finishers, a range of 0.18 - 0.25 percent was specified for tryptophane, 0.20-0.45 percent for cystine, 0.5 - 0.8 percent for methionine, 0.9 - 1.3 percent for lysine. The model also made allowance for the provision of lysine and methionine from synthetic sources if necessary.

(e) Fibre: Birds cannot tolerate high level of fibre in their diets. High fibre content results in lower nutrient intake and digestibility of the proteins. This reduces the extent of utilization of the associated amino-acids. The range specified for both starters and finishers was between 3 and 5 percent.

(f) Fat: Fats are potent sources of energy. They provide 2-3 times metabolizable energy as grains.

Rations high in fat, cake up and do not flow readily. The usual practical limit is 3-5 percent of the diet. With special technologies pelleted diets may have 7-8 percent of added fat.[11] Particularly with the inclusion of cassava up to the 40 percent level, the range specified was between 2.5 - 5.0 percent for both the starter and the finisher rations. This reduces dryness of the feed.

Fats not only serve as energy sources, but they also supply the essential fatty acids particularly linoleic acid which is very important in chick growth. The fat content of the birds diets affect their growth rate particular the sources of the fat which determine its availability of use to the birds.

Fats with unsaturated fatty-acids may not be stable, which leads to axidative rancidity and thus destruction of vitamins A, D and E. It is however very important that chicks get considerable part of their energy supply from fat and not mainly from carbohydrate.

3.2.4: Concluding Remarks

Nutrient deficiencies can result in high mortality rate, reduced livestock performance and consequently low level of profit. It is therefore very important to provide all nutritional factors when formulating diets. The most important classes of nutrients which are crucial to chicks are the protein and essential amino-acids, energy level, fibre, mineral, fat and vitamin conte
The exact quantitative levels of each of these nutrients which will give maximum growth rate are not known but reasonable reliable quantitative data have been obtained from experiments. This is the reason why the model specified a range of values, minimum and maximum levels for the nutrients in Table 3.1.

3.3: Solutions and Discussion of the Model

Using the nutritional and ingredient constraints specified in Table 3.1, Table 3.5 shows the cost and composition of the starter and finisher rations excluding cassava from the ingredient base. Within the framework of the nutritional requirements, the nutrient composition of the ingredients and the cost per unit of each ingredients specified, the rations have been compounded at the least costs of ₦191.67 and ₦175.29 for the starter and finisher rations respectively.

TABLE 3.5: Costs and compositions of the starter and finisher rations excluding cassava

	Ingredients & Nutrients	Starter Ration	Finisher Ration
INGREDIENTS	Cassava	-	-
	Guinea-corn	55.36	56.21
	Brewer's grains	5.00	5.12
	Synthetic Methionine	0.24	0.23
	Blood meal	7.13	9.78
	Palm kernel meal	15.00	15.00
	Salt	0.30	0.30
	Groundnut Cake	12.27	-
	Ad Vit	0.60	0.50
	Wheat Offals	0.54	7.00
	Meat and Bone Scrap	3.56	-
	Bone-meal	-	1.35
	Oyster shell	-	0.51
	Dried Yeast	-	4.00
Cost per ton of mix		₦191.67	₦175.29
NUTRIENTS	Fibre	4.65	5.00
	Calcium	0.07	0.81
	Lysine	1.25	1.30
	Methionine	0.50	0.50
	Phosphorus	0.72	0.80
	Cystine	0.28	0.29
	Tryptophane	0.23	0.21
	Protein	24.00	21.02
	Energy (Kcals./kg.)	2,900	2,800

The finisher ration as expected, is cheaper than the starter ration, by ₦16.38 per ton. The protein levels for the starter and finisher diets are 24 and 21 percent respectively. Calcium phosphorus ratio was 1.2:1 and 1:1 in the starter and finisher respectively. Lysine level was 1.25 for the starter and 1.30 for the finisher. Methionine-cystine combination was 0.78 for the starter and 0.79 for the finisher. In meeting the nutritional specifications at least-cost, the starter ration comes up with a higher energy ration of 2900 metabolizable energy (M,E.) kcals./kg. than the finisher which has only 2800 M.E. kcals./kg.

The differences in composition lie in the fact that the starter ration includes groundnut cake and meat and bone scrap which are excluded in the mix for the finisher ration. On the other hand, the finisher includes bone meal, oyster shell and dried yeast whilst the starter ration excludes them. They both had methionine supplementation from the synthetic source. These levels of nutrients and ingredients meet the specified levels of requirements for chicks. (See Table 3.1).

In Table 3.6 below, the effect of different price levels (C_1 and C_2) on the composition and cost of starter ration, is examined. The first set of costs C_1, represents the average feed producers costs of ingredients obtained from Pfizer and Olaogun commercial feed mixers in September 1976. The second set of costs, C_2, is that of the University of Ibadan Teaching and Research Farm as of June 1977. Table 3.6 shows that the cost of the feed increased by 17.4 percent due to the increase in prices of ingredients from set C_1 to set C_2. The commercial farm's prices are lower than U.I. prices

TABLE 3.6: Effect of changing costs of ingredients on the percentage composition and costs of starter ration, average producer costs, 1976 prices versus U.I. costs, 1977 prices

Ingredients and Nutrients	Av. Producer Costs. C_1	U.I. Costs C_2	Percentage Change
Brewer's grains	5.00	5.00	-
Maize	47.97	-	-
Rice Bran	5.00	-	-
Blood Meal	2.2[illegible]	-	-
Soyabean	10.36	30.00	174
Synthetic Methionine	0.21	0.15	28.7
Meat and Bone	4.20	1.32	68.3
Groundnut Cake	10.50	3.06	83.3
Salt	0.30	0.36	-
Wheat Offals	5.00	5.00	-
Ad Vit.	0.60	0.60	-
Dried Yeast	-	1.03	
Bone Meal	-	0.70	
Oyster shell	-	2.49	
Guinea corn	-	50.34	
Cost per ton of mix	₦160.031	₦187.309	17.4
Protein	26	26	-
Fat	5.0	5.0	-
Fibre	5.18	4.6	9.6
Energy	30[illegible].64	2854.78	48.6
Methionine	0.50	0.50	-
Lysine	1.25	1.25	-
Tryptophane	0.25	0.31	24
Phosphorus	[illegible]	[illegible]	-
Calcium	[illegible]	1.60	100.0
Cystine	0.31	0.36	12.4

for certain feed ingredients because they obtain them directly from suppliers whereas U.I. obtains its supply from contractors. In addition, there has been an increase in the general price level within the period of September 1976 and June 1977.

The tryptophan, calcium and cystine contents increased with 1977 prices by 24,100 and 12.4 percent respectively. The composition of the ration under the two price structures shows marked variation. Guinea-corn replaced maize completely in ration C_2 whilst rice bran and blood meal were excluded. In ration C_1 also, dried yeast, bone meal and oyster shell were completely excluded whilst soyabean, synthetic methionine meat and bone meal and groundnut cake were changed by 174, 28.7, 68.7 and 83.3 percent respectively. The fibre and energy levels also changed by 9.6 and 48.6 percent respectively.

3.3.1 Stability of the Mix of Ingredients to changes in Their Prices in the Starter Ration

There is a range of prices within which each of the ingredients in the mix remain in the solution. Outside this range, that is, if the price of the ingredient falls below the minimum price or rises above the maximum price stated, then it might be totally substituted for or its quantity decreased or increased thus changing the optimum mix.

Table 3.7 below shows the lower and upper price range at which each of the ingredients remain in the solution. The opportunity costs of each of the excluded ingredients are shown also. The opportunity cost is the penalty for including a unit of the excluded ingredient in the solution. Ingredients with equality constraints have no price effect on the stability of the mix. Wheat

TABLE 3.7: Stability of the mix of ingredients to changes in their prices in starter rations

Included Ingredients	Amount %	Price per ton ₦	Range Over Which Solutions Remain Stable	
			Lower ₦	Upper ₦
Dried Yeast	1.03	150	136	186
Soyabean	30.00	150	65	-
Groundnut Cake	3.06	200	182	225
Meat and Bone Scrap	1.32	250	249	287
Bone Meal	0.70	60	12	83
Brewer's Grains	5.00	40	194	-
Oyster shell	2.49	185	96	229
Salt	0.30	210	-	-
Wheat Offals	5.00	70	70	-
Ad Vit	0.60	1355	-	-
Guinea-corn	50.34	220	207	257
Syn. Methionine	0.15	1980	-	2933

Excluded Ingredients	Opportunity Costs (₦)
Fish Meal	442.89
Maize	16.02
Syn. Lysine	2323.22
Dried Milk Powder	104.70
Blood Meal	32.19
Di-Calcium Phosphate	331.69

offals, brewer's grains and soyabean could take up any price above 70, 194 and 55 naira respectively. Also the opportunity cost of increasing the maize content of the mix for example, by one percent is ₦15.02. This is to say that the cost of one tonne of feed will increase from ₦187.81 to ₦202.83.

The composition and costs of the experimental diets are discussed in the later chapters along with the experiments.

CHAPTER FOUR

FEEDING TRIALS

4.1 Introduction

It is one thing for the computerised diets to be least-cost, but it is another thing for them to satisfy the profit maximisation objective of the farmer. For instance, the diets may be too bulky(fibrous) and undigestible for the birds so that very little of the nutrients is absorbed. Also, the diets may be impalatable such that feed intake is considerably reduced. Feeding trials were therefore carried out in order to compare the birds' performance on the formulated diets with the existing commercial diets.

For the purpose of this study, animal performance refers to the feed-growth relationship. Carcass characteristics of broilers are not highly rated in this society and as such, they have not been considered in the study.

4.2 Experimental Diets

4.2.1: Starter Diets for Experiments I and II

Eight starter diets were formulated using varying protein (24 and 26 percent), fibre (3 and 5 percent), and cassava (0 and 5 percent) specifications. The nutrient composition and costs of the different starter diets are shown in Table 4.1.

Protein and fibre levels are known to be major factors affecting the performance of birds. High fibrous diets are too bulky and intolerable for birds. Besides, high fibre content renders the feed undigestable and hinders the absorption and utilisation of the important nutrients. The levels of

TABLE 4.1: PERCENTAGE COMPOSITION OF COMPUTERISED STARTER DIET

Ingredients and Nutrients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8
1. Wheat offals	3.22	4.44	–	3.00	5.00	5.00	5.00	5.00
2. Soyabean	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
3. Maize	56.56	50.94	53.00	45.90	28.64	–	23.60	–
4. Bone Meal	0.91	0.84	0.98	1.10	0.68	0.22	1.20	0.70
5. Syn. Methionine	0.16	0.12	0.17	0.12	0.18	0.15	0.19	0.15
6. Brewer's grain	2.47	–	4.56	2.00	6.00	6.00	6.00	6.00
7. Meat & Bone Scrap	1.75	1.90	2.50	3.20	2.20	2.76	1.00	1.30
8. Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
9. Oyster shell	1.20	1.43	0.80	1.20	1.16	1.30	1.30	1.50
10. Ad. Vit.	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
11. Dried Yeast	2.83	5.00	1.78	5.00	–	0.70	–	1.03
12. Groundnut Cake	–	3.44	–	2.10	–	2.90	–	3.10
13. Cassava	–	–	5.00	5.00	5.00	5.00	–	–
14. Blood Meal	–	–	0.30	8	–	–	–	–
15. Syn. Lysine	–	–	–	–	0.07	–	0.08	–
16. Guinea corn	–	–	–	–	20.20	45.00	30.88	50.30
Cost per ton	N213.36	N209.89	N266.68	N262.67	N253.69	N241.68	N199.34	N187.81
1. Protein	22	26	24	26	24	26	24	26
2. Fibre	3.16	3.16	3.16	3.16	4.26	4.66	4.96	4.76
3. Fat	5	5	5	5.0	5.0	5.0	5.0	5.0
4. Calcium	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
5. Lysine	1.25	1.36	1.25	1.42	1.25	1.25	1.25	1.25
6. Methionine	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.50
7. Phosphorus	0.8	0.8	0.8	0.8	0 8	0.8	0.8	0.80
8. Cystine	0.32	0.34	0.3	0.33	0.32	0.34	0.33	0.35
9. Tryptophan	0.27	0.30	0.27	0.29	0.27	0.30	0.28	0.31
10. Energy	3282.8	3300.7	3274.8	3285.7	3139.1	3087.5	3120	3082

protein and fibre chosen are such that they bracket the adequate ranges which may influence the performance of the birds on the various diets.

Cassava flour is being tested as a substitute for the grains. The effects of the varying protein, fibre and cassava levels are discussed below.

Diets with higher protein levels are less costly than diets with the lower protein levels. This is due to the fact that changes in the optimum mix of ingredients occurs only among the energy providing ingredients which are the costly components. Also, in all cases, there was greater need to use synthetic methionine (very costly component) in the mix to attain the specified level at lower protein levels than at higher levels. Groundnut cake is included in the mix only with feeds containing higher protein levels but in diets with lower protein levels, only soyabean is included and because it is cheaper than groundnut cake, it is included at the maximum level specified before groundnut cake comes into the mix.

Diets including cassava in the mix as substitute for part of the grains are more costly than their counterparts without cassava. For instance, diet 3 costs ₦266.68 per tonne whereas diet 1 costs only ₦213.36 per tonne. Diet 3 substitutes 5 percent cassava for only 3.56 percent maize in diet 1 and the cost difference is ₦53.32 per tonne. The difference between the cost of maize and cassava is ₦70 per tonne. The fibre content specified affects substitution in the ingredients which have high fibre contents. Such affected ingredients are wheat offals and dried brewers grains. These ingredients came in at their maximum levels in the diets with higher fibre content. Other mineral based and vitamin supplying ingredients come into the mix at the various levels so as to make up for the deficiencies of the fibrous, protein and carbohydrate ingredients included in the optimum mix.

4.2.2: Finisher Diets

Two finisher diets were formulated for the second experiment. Their costs and compositions are shown in Table 4.2.

Two protein levels, 20 and 22 percent were specified. It is pertinent to note that these formulations were done mainly to test the two protein levels in the finisher diets. Maize was however totally excluded from the optimum mix due to the fact that it is costlier than guinea-corn and it is not superior to guinea-corn in terms of the nutrient composition. The major difference in the optimum mix is that diet 10 which has the lower protein level includes blood meal which is excluded in diet 9. Also, diet 9 includes synthetic lysine whereas diet 10 excludes it. Diet 10 is however cheaper than diet 9. This conforms to expectations since the diet with a lower protein level should be cheaper.

4.3 The Model

The net revenue to the poultry farmer depends mainly on the rate at which the feed is converted into liveweight gains, the quantity of feed required per unit liveweight gain (feed conversion efficiency), and the optimum market weight consistent with the optimum profit objective.

Growth rate as mentioned before is a function of various factors such as:

TABLE 4.2: Composition and cost of the two finisher diets without cassava

Ingredients & Nutrients	Diet 9	Diet 10
Guinea-corn	63.36	59.75
Groundnut cake	15.70	11.39
Brewer's grain	7.52	8.00
Wheat offals	5.42	7.00
Blood meal	-	5.64
Dried Yeast	4.00	4.00
Oyster shell	1.48	1.56
Bone meal	1.44	1.45
Synthetic Methionine	0.03	0.44
Ad. Vit.	0.50	0.50
Salt	0.30	0.30
Synthetic Lysine	0.26	-
Cost per tonne of mix	₦203.23	₦187.15
Protein	.	
Fibre	4.50	4.60
Lysine	1.26	1.10
Fat	3.65	3.90
Calcium	0.80	0.80
Cystine	0.30	0.26
Methionine	0.50	0.50
Tryptophan	0.23	0.23
Phosphorus	0.40	0.40
Energy	2882.38	2906.52

i) the quality of the diet,

ii) the genetic characteristics of the experimental birds,

iii) the environment which involves experimental conditions such as temperature, space (stocking density) and ventilation.

iv) management, which involves the feeding, watering, sanitation practices and state of health of the birds.

In the feeding trials, all the above factors were kept constant except the quality of the diets.

In symbolic terms, the relationship between weight gain, feed intake aad other factors affecting growth can be expressed as follows:

$$G = f, (X_1, \ldots\ldots, X_n, X_{n+1}, \ldots\ldots, X_m, X_{m+1}, \ldots\ldots, X_p, X_{p+1}, \ldots X_q$$

where, G = growth rate

$X_1 \ldots X_n$ = nutritional factors which determine the quality of the diet

$X_{n+1} \ldots\ldots X_m$ = genetic characteristics

$X_{m+1} \ldots\ldots X_p$ = Environmental conditions

$X_{p+1} \ldots\ldots X_q$ = Management.

Through experimental design, $X_{n+1} \ldots\ldots X_q$ could be assumed constant, and the weight gain-feed intake model reduces to $G = f(X_1, \ldots\ldots, X_n)$. Feeding trials were carried out to establish in quantitative terms the true relationship of the above model for the various computerized and commercial diets I and II.

4.4 Experimental Design and Setting

The design of experiment used is a randomised block layout. One of the two most important conditions in a randomised design is that there should be two or more treatment levels which may differ either qualitatively or quantitatively. The second condition is that the experimental subjects should be randomly assigned to the treatment levels. This particular design has a very useful advantage in that it is not compulsory for the number of birds to be equal under each diet. This applies to cases where occasional deaths occur or in case of disease outbreaks. However, the same number of birds were randomly assigned to each diet initially. Each replicate had the same floor space (1.8 sq ft. per bird) and all birds received the same medication throughout the duration of the experiment.

Birds were fed and watered ad libitum in groups. At the end of each week, group measurements of the feed intake and weight gains were taken. Group measurements had to be taken because wing tags were not available to differentiate one bird from the other. Also, because the deep litter system of management was used, it was not possible to obtain individual feed intakes.

4.5 Broiler Birds and their Management

Prior to the arrival of chicks, care was taken to ensure that all equipment were clean and in good operating condition. Heating was done at least 24 hours before chicks arrived especially when a new consignment arrived during the wet season.

Adequate feeders and waterers were provided for the birds. Waterers were filled a few hours ahead of arrival so the water was at room temperature when the chicks arrived. Antibiotics and vitamins were administered in the drinking water for the first one week to give the chicks a good start in life.

Overhead lights were provided for the first few days when chicks arrived in order to help the chicks find feed and water. Thereafter, only the attraction lights under the brooder boxes were provided. This was to prevent crowding and straying. Feed and water were provided at all times.

The birds were vaccinated as advised by the veterinary doctor. At day old-intra-occular vaccine against new castle and at 4 weeks intra-muscular vaccine against foul pox were given to the birds. After clearing off each batch of birds, the house was thoroughly cleaned and disinfected.

4.6 Limitation of the Experiments

Three important things proved to be limiting in the conduct of the experiments:-

4.6.1: Feed Ingredients

Feed ingredients were not stored under optimum conditions so that sometimes they have been infested by weevils. This affects the nutrient contents of the ingredients. Feed samples were however taken for analysis and were found to contain the stated protein, fibre and fat contents for each of the diets.

4.6.2: Housing

Ideally, after each batch of birds, the house should be thoroughly washed and disinfected all over. The house should then be left for at least four weeks before rearing another batch in the same house. Unfortunately, this was not possible on the Teaching and Research Farm in view of the numerous research projects being carried out and the pressure for research time and space by every user. The resting period in these experiments was two weeks after thorough cleaning and disinfection. Despite these thorough cleaning the continuous cropping in the houses resulted in a build up of diseases in the houses and these were passed on to each new flock reared in the houses. It was therefore very difficult to prevent incidence of diseases in the experimental birds. However, the effects were reduced to a minimum by administering drugs as preventive and curative measures. Post-mortem examinations were done as soon as deaths occurred to determine the cause of the deaths.

4.6.3: Methods of Measurements

The problem here as mentioned earlier is that birds could not be weighed individually because there were no wing tags to identify them. Group weighing has been practised in various studies by Dent,[15] Heady and Dillon [27] and they have shown that the method does not adversely affect the results, but rather helps in the regression analysis by eliminating certain statistical problems like autocorrelation even though it results in the loss of some degrees of freedom.

4.7: Experiments and Performance Comparisons

4.7.1: Experiment 1: Comparison of Eight Computerised Diets of Varying Protein, Fibre and Cassava Contents

The compositions of eight starter diets tested were earlier presented as Table 3.8. The composition of the two commercial diets tested as control are not available because the feed compounders never want to reveal their formulae. The labels found on the various types of commercial feed only show the ingredients used and the proximate analysis of the percentage levels of protein, fibre and fat in the feed.

The objective of this experiment was to compare the performance of the birds fed each of the starter diets with varying levels of protein, fibre and cassava. Two protein levels - (24 and 26 percent), two fibre levels - (3 and 5 percent) and cassava levels - (0 and 5 percent) were the different combinations of the eight diets. These diets had the following levels of the different components:

Diets	Protein	Fibre	Cassava
(1)	24	3	0
(2)	24	3	5
(3)	24	5	0
(4)	24	5	5
(5)	26	3	0
(6)	26	3	5
(7)	26	5	5
(8)	26	5	0

(a) Breed and Stocking Rate

The particular breed used in the experiment is the Cobb broiler. The Cobb is a dominantly white feathered bird that has been bred specially for broiler qualities. It is noted for its high growth rate, early feathering and good feed conversion rate. However, it succumbs very easily to disease outbreaks.

Six hundred day old broiler chicks were randomly distributed to ten pens such that each pen contained 60 birds. Each pen was randomly allocated to each of the ten experimental diets (eight computerised and two commercial diets.)

(b) Mortality

A record of daily mortality was kept for each of the pens throughout the experimental period. Mortality rate was nine percent in the whole flock even though the highest number of deaths occurred in only two of the pens.

(c) Performance Comparison of Eight Starter and Two Commercial Diets: The experimental results are presented below: Records of feed intake and liveweight gain are shown in Appendix A. Figures in Table 4.3 below are mean values for the various treatments. The t-statistic is used to test for significant differences among the means.

Table 4.3 summarises the performance comparisons of the birds on the starter diets based on efficiency yardsticks of average weight gain, average feed intake for the period of six weeks and the efficiency of feed conversion.

Column two of the table shows that there were significant ($P < 0.01$) differences between the average total weight gained by the birds on the various diets used. From column three and four, it can be deduced that commercial II starter required the least quantity of feed to put on one kilogram liveweight and the t-test shows that there were significant ($P < 0.01$) differences in the feed intake and feed conversion efficiency. Diets 3, 4, 5 and 6 contained five percent level of cassava and they have been consumed in the same manner as the other diets. Diet 5 performed best among the eight computerised diets in terms of feed efficiency (3.10) and this was significantly ($P < 0.01$) different from the values recorded for the other diets.

4.7.2: Experiment II: Selecting the best pair of Computerised Starter and Finisher Diets

The main objective of this experiment was to test starter and finisher diets concurrently so that it would be possible to select the best pair in terms of least-cost and best response.

TABLE 4.3: Performance comparison of ten starter diets

1 Diets*	2 Average weight gain (6 weeks) (kg)	3 Average Feed Intake (6 weeks) (kg)	4 Feed/Weight Feed Conversion Efficiency (F.C.E.)
Diet 1	0.623	2.01	3.23
Diet 2	0.605	1.99	3.29
Diet 3	0.521	2.14	4.11
Diet 4	0.585	1.97	3.37
Diet 5	0.620	1.97	3.18
Diet 6	0.536	2.01	3.75
Diet 7	0.624	2.08	3.33
Diet 8	0.540	1.97	3.65
Comm. I	0.668	2.16	3.23
Comm. II	0.651	1.77	2.72
Mean	0.5973	2.007	3.386
Standard Error	0.204++	0.109++	0.376

+Diets are as listed in Table 4.1 above.

++Significant at $P \leq 0.01$

Due to lack of space and funds, only two starter diets and two finisher diets were tested with two commercial diets as control.

Two computerised starter diets 2 and 7 of Table 3.8 were selected from the first experiment because they had lower costs than the rest and performed best among the diets without cassava. The compositions of the two computerised finisher diets are shown in Table 4.2.

(a) Breed and Stocking Rate

The same breed of broilers was used as in experiment 1. Three hundred day-old broiler chicks were randomly distributed into 12 pens such that each pen had 25 birds. The two chosen computerised starter diets were allocated to eight of the pens such that each had four replicates. The two commercial diets were allocated to the remaining four pens such that each had two replicates. This is also due to lack of space and funds. After six weeks the birds were transferred to the computerised and commercial finisher diets and reared to the age of 12 weeks. There were four replicates of the starter and finisher rations. The chart below shows the structure of the experimental diets.

Starter	Diet 7	Diet 7	Diet 7	Diet 7	Diet 2	Diet 2	Diet 2	Diet 2	CI	CI	CII	CII
Finisher	Diet 10	Diet 10	Diet 9	Diet 9	Diet 10	Diet 10	Diet 9	Diet 9	CI	CI	CII	CII

(b) Mortality

There was high incidence of mortality in two of the pens, on each of the diets. The mortality was about 17 percent on the whole. Results from postmortem examinations revealed fatty liver syndrome which may be caused by the high energy; protein ratio of the diets. The highest mortality was recorded on very hot days. Appendix B summarises the average weekly feed intake and liveweight gains for each of the diets.

<u>Performance Comparison</u>

Tables 4.4 and 4.5 show the performance comparison of the starter and finisher diets, respectively.

Analysis of variance tests were performed on columns 2-4 of Table 4.4 (see ANOVA tables 4.4.1-4.4.3) which show that there were significant ($P \leq 0.05$) differences between the averqge weight gains, average feed intake and feed conversion efficiency for the birds on each diet. To detect the treatment causing these differences the criterion of lsd+ was used. Using the criterion of weight gains, significant differences ($P \leq 0.01$) were shown between diets 2 and 7, II and 7 and I and 7. It can be deduced therefore that diet 7 was the best out of the starter diets in terms of weight gains. With feed intake, however, significant ($P \leq 0.01$) differences were prominent in diets 2 and 7, 2 and II, I and II and I and 7. Diets 2 and I and 7 and I were not consumed significantly more than each other. The most acceptable

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+lsd means least significant difference. It is derived statistically using the formula

$$d = t_{\alpha} \sqrt{\frac{2S^2}{r}}, \quad t_{\alpha}, (n-1)(k-1) \text{ d.f.}$$

where

r = number of observations per mean
n = number of replicates, k = number of treatments
S^2 = error variance
α = level of significance

Differences between two pairs of means which are greater than d are significant.

TABLE 4.4: Performance Comparison of the starter diets

1 Diets+	2 Average Weight Gain (6 weeks) (kg.)	3 Average Feed Intake 6 weeks (kg.)	4 Feed/Weight Feed Conversion Efficiency (F.C.E.)
Diet 2	0.587	1.60	2.73
Diet 7	0.770	1.86	2.42
Commercial I	0.635	1.81	2.85
Commercial II	0.646	2.28	3.52
Mean	0.66	1.89	2.88
Standard Error	0.135	0.285	0.469

+Diets are those tested in experiment I. They have the lowest costs out of the least-cost (computerised) diets and were found to perform best among the diets without cassava.

TABLE 4.4.1: ANOVA table for weight gains

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05(3,8)}$ $F_{0.01(3,8)}$
Treatment	0.068	3	0.023	7.67^{++}	4.07
Error	0.021	8	0.003		7.59
Total	0.039	11			

TABLE 4.4.2: ANOVA table for food intake

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	F	$F_{.05(3,8)}$ $F_{.01(3,8)}$
Treatment	0.609	3	0.203	14.6^{++}	4.07
Error	0.114	8	0.014		7.59
Total	0.723	11			

TABLE 4.4.3: ANOVA table for feed conversion efficiency.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F	$F_{.05(3,8)}$ $F_{.01(3,2)}$
Treatment	1.71	3	0.59	5.18^{+}	4.09
Error	0.86	8	0.11		7.59
Total	2.57	11			

$^{+}$Significant at $P < 0.05$

$^{++}$Significant at $P < 0.01$

starter diet to the birds was therefore commercial II. In terms of feed conversion efficiency, significant ($P < 0.01$) differences occurred between diets 2 and II, I and II and 7 and II. The best diet was starter diet 7, followed by diet 2 which were not significantly ($P < 0.01$) different from each other. Commercial II diet performed poorest.

(d) Conclusions on Starter Diets

The starter diets which included five percent cassava performed as well as those without cassava. Diets with 24 percent protein and 5 percent fibre levels were better than those with 25 percent protein and 3 percent fibre levels. The two computerised starter diets in the second experiment were the cheapest and they were found to perform better than the commercial diets. There is no doubt that differences occur in the performance of the diets and this could be derived in economic terms. In achieving this, the costs of the various feeds and the value of weight gained are considered. This aspect is dealt with in a later chapter.

4.7.3: Finisher Diets

The results for the finisher diets are summarised in Table 4.5. The figures in the table are mean values for the various treatments. Analysis of variance tests were performed on columns 2-4 of Table 4.5 (See Anova Tables 4.5.1 - 4.5.3) which show that there were no significant ($P < 0.05$) differences between the average weight gains, average feed intake and feed conversion efficiency for the birds on each diet.

TABLE 4.5: Performance comparison of two finisher diets with two commercial diets

Diets[+]	Average Weight gain (kg.)	Average Feed Intake (kg.)	Feed/Weight Feed Conversion Efficiency (F.C.E.)
Diet 9	1.20	3.62	3.01
Diet 10	1.17	3.69	3.15
Comm. I	1.20	3.93	3.28
Comm. II	1.07	3.86	3.63
Mean	1.16	3.80	3.27
Standard Error	0.0616	0.1257	0.2378

[+]Compositions of diets 9 and 10 are in Table 4.2
Commercial diets are the same as those used in experiment I.

TABLE 4.5.1: ANOVA table for weight gains

Source Variation	Sum of Squares	Degree of Freedom	Mean Square	F	$F_{0.05(3,8)}$ $F_{0.01(3.8)}$
Treatment	0.071	3	0.024	1.143	4.07
Error	0.167	8	0.021		7.59
Total	0.238	11			

TABLE 4.5.2: ANOVA table for feed intake

Source Variation	Sum of Squares	Degree of Freedom	Mean Square	F	$F_{0.05(3,8)}$ $F_{0.01(3,8)}$
Treatment	0.301	3	0.10	1.449	4.07
Error	0.551	8	0.069		7.59
Total	0.852	11			

TABLE 4.5.3: ANOVA table for feed conversion efficiency

Source of Variation	Sum of Square	Degrees of Freedom	Mean Square	F	$F_{0.05(3,8)}$ $F_{0.01(3,8)}$
Treatment	0.0723	3	0.241	1.346	4.07
Error	1.429	8	0.179		7.59
Total	2.152	11			

Although the differences between the performance of these diets are not significant (P < 0.05), it could be observed that slight variations still occurred. Columns three and four of Table 4.5 show that the commercial diets needed more feed to put on one kilogram of weight. This implied that the computerised diets used less feed and since they happened to be cheaper[+] than the commercial diets, they would give more returns to the farmer. The results confirmed that the diets were nutritionally balanced.

However, it is of interest to determine the best combination of starter and finisher diets.

The analysis for this is presented in Table 4.6. Comparison is mainly on the basis of feed conversion efficiency. Column four shows that the best pair of diets is using starter 7 with finisher 9. Also, all the computerised starter and finisher combinations proved better in F.C.E. than the two commercial diets. It is pertinent to note that none of the computerised

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[+]Prices of computerised diets were increased by 22.48 percent to make up for the overhead charges which the commercial diets included. The figure was recommended by Ogunfowora, et. al. (56). The costs derived are thus:

Diet 9	₦250/ton
Diet 10	₦230/ton
Commercial I	₦300
Commercial II	₦300

TABLE 4.6: Performance comparison of the computerised starter and finisher diets with two commercial diets

(1) Diets+	(2) Average Weight Gain (kg.)	(3) Average Feed Intake (kg.)	(4) Feed/Weight Feed Conversion Efficiency (F.C.E.)	(5) No. of days	(6) Average Daily Gain (kg.)	(7) Average Daily Feed Intake (kg.)
Diets 2 & 9	0.587	1.60		42		
	1.20	3.69		35		
	1.787	5.29	2.96	77	0.023	0.069
Diets 7, 2 and 10	0.587	1.60		42		
	1.17	3.69		35		
	1.757	5.29	3.01	77	0.023	0.069
Diets 3, 7 and 9	0.770	1.86		42		
	1.20	3.69		35		
	1.970	5.55	2.82	77	0.026	0.072
Diets 4, 7 and 10	0.770	1.86		42		
	1.17	3.69		35		
	1.940	5.55	2.86	77	0.025	0.072
5 Comm. I	0.635	1.81		42		
	1.2	3.93		35		
	1.835	5.74	3.13	77	0.024	0.075
6 Comm. II	0.645	2.28		42		
	1.07	3.88		35		
	1.715	6.16	3.59	77	0.022	0.08
Mean			3.06			
Standard Error			0.5966			

+ See Tables 4.1 and 4.2.

starter and finisher diets in experiment II contained cassava flour.

4.8: Empirical Estimation of Parameters Affecting Broiler Diets

Regression analysis has been performed in order to investigate the functional relationship between the feed intake levels of the various starter and finisher diets and liveweight gains. Experimental results shown in Appendix (B) were used for the regression analysis.

Solutions to econometric problems and the choice of functional forms are discussed below.

Violation of the assumption of non-autoregression in the linear regression analysis poses a problem. Here autocorrelation occurs because each weekly weight of the birds is dependent on the weight of the birds at the end of the previous week. Also, since the birds were fed in the same manner over the experimental period, it is most likely that a group will consistently be above or below average, resulting in successive observational error which is positively correlated [22/]. The consequences of such autocorrelated variables are given by Koutsoyiannis [37/] as follows:

(a) Although the estimated parameters are statistically unbiased, their value in any single sample is not correct.

(b) The variance of the random error or disturbance term may be seriously underestimated if the disturbance terms are autocorrelated. In particular, the underestimation of the variance of the error term will be more serious in the case of positive autocorrelation. Hence the variance of the error term will be seriously underestimated, and consequently, the variances of the estimated parameters will be underestimated, especially if the method of ordinary least-squares is applied.

c. The variances of the estimated parameters are underestimated when ordinary least squares method of estimation is used. Therefore, with a false smaller variance, the reliability of the estimates is exaggerated. An estimate can therefore be regarded as being reliable when actually it is not.

However, Heady and Dillon[28] suggested one way of removing autocorrelati by reducing the analysis to a static (timeless) one by regressing total weight gain for the birds on total feed intake. This would only lead to a reduction in the degrees of freedom, but the remaining degrees of freedom are still enough to enable the estimation of reliable substitution rates and coefficient of determination (R^2).

Another method used by Dent [16] is to use average value for live weight gain and feed consumed over the growing period. The disadvantage is also that of loss in degrees of freedom.

Lastly with the assumption of perfect positive autocorrelation, the method of first difference can be applied to the cumulative values used in the regression analysis, according to Heady and Dillon [28], Koutsoyiannis [37] This is exactly the same thing as regressing the observations on weekly liveweight gains on weekly feed intake values.

For the purpose of this study, average values of the replicates were used instead of the individual observations because of the nature of the experiments. Firstly, the birds are fed ad libitum, and it becomes necessary that either the time intervals of taking readings are fixed or the quantity of feed consumed is predetermined. It is however, not possible to control both at the same time. Usually, observations on feed consumption and weight gains are taken at fixed intervals of time such as a week or month. Weekly observations are made in this study. Secondly, the birds are self fed with full time access to the feed and so the amount of feed consumed is determined by the particular bird thus making it a random variable which is endogenous. It is therefore measured with error and the estimated production coefficients will be biased. Thirdly, individual gain in weights of birds could not be measured since there was no means of identifying each bird and the amount of feed consumed by each bird or the weight gained by each bird.

4.8.1: Functional forms employed

Two types of algebraic equations were fitted to the experimental data namely the Quadratic and Square root functions. Quadratic and Square root functions have isoclines that converge to a point, allowing specification of one ration consistent with maximum meat production. Also, the quadratic function allows diminishing and negative marginal products, and also defines a maximum. A limitation of the quadratic form is that it imposes linearly decreasing marginal products which may be a poor approximation to the true biological form of the production process. Heady and Dillon [28] found the quadratic function to be acceptable.

The isoquants of both the quadratic and square root functions are not asymptotic to the input axes but rather they intersect the input axes so that certain output levels can be attained using either of the inputs only. The only difference in the shape of isoclines of the quadratic and square root functions is that the isoclines of the square root function pass through the origin so that it compromises between the Cobb-Douglas and Quadratic functions. The isoclines of the square root do not specify a fixed mix of resources for attaining different output levels as do the isoclines of the Cobb-Douglas function, and it does not impose linear isoclines as the Quadratic function.

4.8.2: <u>Regression Results</u>

(a) <u>Criteria for Selecting the Lead Equation</u>

To determine whether the regression results are good or bad, the following factors have to be considered:

(i) R^2 - This reveals the goodness of fit. It shows the contribution of the regressors to the explanation of variability in the dependent variable. Simply, it gives the percentage of the dependent variable explained by the independent variables.

(ii) Dubin-Watson statistic (DW) - This test helps to reveal whether the assumption of non-autoregression is violated or not. The value obtained in the regression results should be between the upper and lower values obtained from the table.

$DW \leq dL$ Autocorrelation occurs.

$DW > dU$ No autocorrelation

$dL \leq DW \leq dU$ Indeterministic

where

dL = Lower table value of DW statistic

dU = Upper table value of DW statistic.

(iii) Signs - The estimated parameters must bear signs which correspond to the type of correlation between the dependent and explanatory variables from apriori knowledge. Explanatory variables are either positively or negatively related.

(iv) F test - The F value in the regression result is compared to the table F value and if significant, means that the explanatory variables make significant contribution to the dependent variable.

(v) Standard error or t-test - These two serve the same purpose of determining the significance of individual explanatory variables. The main difference is just that the standard error gives a rough estimate. The standard error value is significant so long as it is about half the regression coefficient. The t-statistic which makes use of the standard error provides the test-statistic which shows whether a particular regression coefficient is significantly different from zero or not.

If F is significant but the t-tests are not significant, then multicollinearity poses a big problem. In a single linear regression, the F and t tests coincide and they serve the same purpose. The significance of the tests reveals that the individual explanatory variables are making significant contributions to the dependent variable.

(b) Effect of Feed intake on liveweight gain

This section enables proper comparison of the computerised and commercial diets. The relationship that exists between feed intake and liveweight gain are established in functional forms by regressing average weekly feed intake on liveweight gain. As established in section 4.2 of this chapter, if genetic and environmental factors are well controlled, variations in weight gains are due largely to the level of feed intake. Feed however, is a function of its nutrient contents. Here, the level of feed intake is the subject of discussion. The nutrient contents are dealt with in a later section. The relationship between feed intake and liveweight gain thus established will enhance the possibility of forecasting what quantity of feed produces an output of broiler meat as well as comparing the marginal analysis with feed conversion efficiency (technical analysis).

(i) Methodology

Weekly records of feed intake and liveweight gains were taken as raw data. Average weekly figures per bird were derived. However, to solve the problem of autocorrelation which occurs in a times series experiment such as described earlier in the introduction of this section, the method of first difference was applied to the cumulative values of these average weekly figures of feed intake and liveweight gain. This in effect is the same as using the average weekly figures.

(ii) Estimating Procedures

The model to be tested was a feed response model whose mathematical representation can be written as follows:

$$W = f(X, V)$$

where W = Average weekly liveweight gain, X = Average weekly feed intake

V = Error term.

In estimating the parameters of the feed response model, two functional forms were tried namely:-

Quadratic: $W = a + bX + cX^2 + V$ (eq. 4.1)

Square root: $W = a + bX + cX^{\frac{1}{2}} + V$ (eq. 4.2)

From the time-series data collected during the experiment, the parameters of the feed response model were estimated for the computerised and commercial starter and finisher diets. The empirical results are presented below:

(iii) Empirical Results

For all the different diets, the quadratic form gave the "lead" equation in terms of the criteria listed in section 4.8.2a above. The functions for the starter diets are presented in Table 4.2.

In these starter diets, feed intake was found to be an important explanatory variable as measured by the F-tests (significant at $P < .01$) and the percentages of the variabilities in liveweight gain explained (R^2) The R^2 values ranged from 72-89 percent. This high explanatory power for feed intakes in these diets means that the nutrient balance and availability situation were such that intake was not affected and most of the feed consumed was used directly for growth purposes. The D.W. test statistic shows no autocorrelation in all the diets which suggests that the equations can be used for inferential purposes. From apriori knowledge, X, (feed intake)

Table 4.7: Empirical results of weight response to feed intake in starter diets

Diets	Dependent Variable	Constant Term	Independent Variables		R^2	F	D.W	dL	dU	Eq No
	W		X	X^2				α = 0.05		
Diet 2	W	-0.008	0.75 (0.38)++	-11.09 (5.60)+	0.78	34.7+	1.67	1.27	1.45	4.
Diet 7	W	-0.004	0.48 (0.25)++	- 0.015 (0.01)	0.88	60.91+	1.85	1.27	1.45	4.
Comm I	W	-0.0072	0.72 (0.35)++	-55.63 (22.32)	0.89	51.42+	2.14	1.27	1.45	4.
Comm II	W	0.046	0.33 (0.15)++	-42.08 (20.13)++	0.72	9.0+	1.56	1.27	1.45	4.

where R^2 is the coefficient of determination.

D.W. is the calculated Durbin Watson statistic

F is the F-statistic

Figures in parentheses are standard errors of the regression coefficient

\+ denotes significance at $P < 0.01$

++ denotes significance at $P < 0.05$

All other variables are as previously defined.

conforms with the expectations of positive correlation with the regressors and (liveweight gain). One expects that liveweight gain should increase as feed intake increases. The functions for the finisher diets are presented in Table 4.8.

In these finisher diets, feed intake was also found to be an important explanatory variable as measured by the F-tests (significant at $P < 0.01-0.05$) and R^2 values. R^2 values ranged from 83-92 percent except for commercial I diet which had 54 percent. In this commercial I diet, where R^2 was as low as 54 percent, it would appear that growth rate was influenced by some other factors other than feed intake *per se*. These other factors could include reduced digestibility and hence lowered availability of nutrients or even an unbalanced pattern of amino acids. This situation is not noticeable in the computerised diets (and commercial II) where restrictions in the model used in formulating them have been specified such that at least a balanced pattern of amino-acids is maintained.

The regressor picked the correct sign except in computerised finisher diet 10. The Durbin-Watson test statistic is undeterministic in equations 4.9 and 4.10. There is doubt therefore as to whether serial correlation occurs among the residuals. The estimated equations are however, still useful for predictive purposes. The commercial starter and finisher diets were similar in the way they influenced liveweight gains in terms of accounting for variabilities in liveweight gain and their marginal physical productivities (MPP) are discussed below.

Table 4.8: Empirical Results of Weight Response to Feed Intake in Finisher Diets

Diets	Dependent Variable W	Constant Term	Independent Variables X	X^2	R^2	F	D.W	dL $\alpha = 0.05$	dU	Eq. No.
Diet 9	W	0.008	0.365 (0.17)++	-0.014 (0.31)	0.8[illegible]	20.95+	1.84	1.20	1.41	4.[illegible]
Diet 10	W	0.356	-0.35 (0.16)++	56.[illegible] (22.[illegible])+	0.92	50.3+	1.58	1.20	1.41	4.[illegible]
Comm. I	W	-13.02	0.54 (0.28)++	-0.03 (0.09)	0.54	2.05++	1.31	1.20	1.41	4.[illegible]
Comm II	W	-14.68	0.51 (0.25)++	-0.05 (0.01)+	0.91	25.13+	1.31	1.20	1.41	4.[illegible]

All variables, parameters and symbols are as previously defined.

4.8.4: Comparison of Marginal Physical Product with Feed Conversion Efficiency

The marginal physical productivities of each of the diets is obtained by differentiating the estimating equations of each of the diets 4.3 – 4.10 with respect to feed intake. The F.C.E. values are those observed in Tables 5.2 – 5.3. The marginal physical productivity is comparable to Feed Conversion Efficiency in the sense that both are measuring the additional weight gain if one more kilogram of feed is consumed.

MPP is obtained from $\frac{dW}{dX}$ for each of the equation $W = a + bX \pm CX^2$.

Starter 2	$\frac{dW}{dX} = 0.75 - 22.10X$	4.3.1
Starter 7	$\frac{dW}{dX} = 0.48 - 0.03X$	4.4.2
Finisher 9	$\frac{dW}{dX} = 0.366 - 0.028X$	4.5.3
Finisher 10	$\frac{dW}{dX} = -0.35 + 113.55X$	4.6.4
Comm I Starter	$\frac{dW}{dX} = 0.72 - 111.26X$	4.7.5
Comm II Starter	$\frac{dW}{dX} = 0.33 - 84.13X$	4.8.6
Comm I Finisher	$\frac{dW}{dX} = 0.54 - 0.06X$	4.9.7
Comm II Finisher	$\frac{dW}{dX} = 0.51 - 0.10X$	4.10.8

The MPPs and the corresponding FCEs for the various diets are presented below:

Diets	MPP	F.C.E.	$\frac{1}{\text{F.C.E.}}$
Computerised Diets			
Starter diet 2	0.7493	2.73	0.37
Starter diet 7	0.4840	2.42	0.41
Finisher diet 9	0.3651	3.01	0.33
Finisher diet 10	0.3524	3.15	0.32
Averages	0.4877	2.83	0.35
Commercial Diets			
Commercial I Starter	0.7210	2.85	0.35
Commercial II Finisher	0.5408	3.52	0.28
Commercial I Finisher	0.3342	3.28	0.31
Commercial II Finisher	0.5144	3.63	0.28
Averages	0.5276	3.32	0.30

Marginal Physical Productivity (MPP) is a measure of the increase in liveweight gain when an additional unit of feed is consumed. On the other hand, Feed Conversion Efficiency (FCE) is a technical measure of the quantity of feed required to produce one kilogram of liveweight. Taking the inverse of FCE, makes it comparable outright with MPP.

On the average, an intake of one kilogram of both the commercial and computerised diets produces approximately 0.5 kilogram of liveweight gain. Comparison of the MPP with FCE values for these diets show some variations. The MPP for the commercial diets is higher than that for the computerised diets but the FCE for the computerised diets is much better than that for the commercial diets. For the computerised diets, FCE shows that one kilogram of feed produces 0.35 kilogram of liveweight gain whereas for the commercial diets it produces only 0.30 kilogram of liveweight gain.

Summary and Conclusions

It has been established that feed intake is an important explanatory variable in liveweight gains as shown by the R^2 values (54-92 percent) and F-test (statistically significant $P < 0.01$) of the estimated equations. The computerised diets compare well with existing commercial diets, as shown by FCE and MPP values (differences in FCE were found not to be statistically significant). The computerised diets however have an edge over the existing commercial diets because they have better FCE and they are cheaper and would therefore increase the net revenue accruing to the farmer. (Prices in page 58).

CHAPTER FIVE

CASSAVA AS A SUBSTITUTE FOR MAIZE AND GUINEA-CORN IN POULTRY (BROILER) FEED

5.1 Introduction

Up till now, grains have been the main energy sources in poultry feeds. The demand for grains for human consumption is so high that the supply in the country cannot meet it. This has led to high importation of corn in very large quantities to meet the demand for both human and animal consumption. In addition, there is also the need for industrial manufacture of dextrin for the production of glucose as well as starch for the textile industry. This high demand for maize has led to very steep rises in the price of maize in the last five years. Search for alternative sources of energy in compound feeds have shown that cassava and sweet potato have considerable potential. This study tested cassava as a substitute for the grains. Cassava, despite its low cultivation has been chosen as a substitute because of its other good characteristics which are discussed below.

Emphasis would be placed mainly on finding out the rate of substitution between the grains and cassava as well as the economics of the use of cassava. The prevailing price of cassava is higher than that of the grains and this condition may not be so in future if production increases and use is made of the existing improved technology. This has prompted the adoption of parametric programming to test the effect of varying cassava prices on the total cost of a given weight of broiler ration. The response of the birds with increasing levels of cassava in the diets is also of utmost interest.

The returns accruing to the farmer with the use of cassava based diets will be compared to the grain based diets. The optimum combination of maize/cassava and guinea-corn/cassava will also be determined.

5.2 Characteristics

Cassava, apart from being an all season crop, has a very high photosynthetic potential thus making it the highest energy yielding per hectare crop. 61/ 52/ The high yield/hectare makes it one of the cheap sources of carbohydrate. It is easily propagated from cuttings and very resistant to pests, weeds and diseases. It has the ability to tolerate drought and poor soils and poses fewer storage problems than the grains. It is therefore interesting to explore the possibilities of using cassava as a close substitute for the major sources of energy in livestock feeds which are as of now largely made up of maize and guinea-corn.

The problem of toxicity is being overcome mainly via plant breeding techniques which select for low hydrocyanic acid yield and through efficient processing techniques which eliminate the toxic constituents. Processing may however add to the cost of the product.

Cassava has many alternative uses, most important of which is its use as staple food in almost all parts of Nigeria. It is also being used for industrial purposes, for example in textile industries and for making starch.

5.3 Factors Affecting Cassava Production

Despite all the qualities of cassava, it is only recently that more systematic and sophisticated methods of cassava cultication have been employed.[9/] [39/] The main factor retarding its extensive use as livestock feed is the presence of cyanogenetic glucosides which make it toxic to animals.[40/] Fortunately, however, is the fact that it is water soluble and breaks down under high temperatures. Elimination of the cyanogenetic glucosides is the aim of traditional methods of processing which entails either soaking for many days before sundrying or roasting or grating and fermenting for three days before roasting. Cassava has been discredited as human or animal food because of its low protein content. It is essentially an energy food and indications now are that the future food shortage in developing countries may give cassava a new importance so that farmers may shift to producing it on a large scale.

Cassava is highly soil-depleting and farmers resort to its production only when soils can no longer give good harvest for other crops. Also, it gives a lower income to the producers but it compensates by giving higher yields per unit of hectare. Other factors affecting the cultivation of cassava include low level of knowledge of agronomical practices and cassava potentials coupled with unorganised marketing system of the cassava roots.

5.4 Price comparisons

As of now, cassava flour seems to be more costly than the grains. A few factors which could be shooting up the costs of cassava flour are difficulties in handling, storage, processing and marketing of the root crop.

Processing has the greatest relevance to the high price of cassava flour in animal feeds. The peels of the root contain a phosphorylase inhibitor [61/] which prevents the liberation of the enzyme lynamarase. The enzyme allows free Hydrogen cyanide (HCN), the toxic substance in cassava to be liberated from the cyanogenetic glucosides present in the tubers. The rind of the tubers therefore must not be present in the root meal during processing. This processing stage may therefore necessitate more labour. Most of the processing to date is by manual traditional methods. The development of machinery for the bulk processing of cassava may reduce the cost and increase the volume of flour available for livestock feed production. Since labour is a very costly factor of production in our economy, it is highly contributory to the high cost of cassava flour.

All that is needed then is more efforts on research as regards the development of high yielding varieties coupled with better agronomical practices and processing techniques.

Now that most imported products are being bann d or restricted to conserve our foreign exchange earnings, maize may come to be affected. As of now, maize is largely imported at a much lower cost compared to the cost of cassava flour and non-imported maize. Also, seasonal production is reflected in the cost of cassave because cassava prices vary from one season to another. Until excess cassava left over after human consumption can be processed and stored for livestock use, seasonal price variations will continue.

With great opportunities opened to us in research, it is hoped that larger quantities would be produced and made available at lower costs. This is possible if research findings are fully adopted and incorporated into peasant farming and large scale farming systems. Thus its inclusion in the diet will not inflate the cost of the feed unrealistically.

5.5 Previous Studies

5.5.1: The review

A lot of work has been done on the feeding of cassava to both pigs and poultry.

There are various forms of dry commercial feeding products from the cassava plant. They are in chips, pellets, rectangular bars, broken roots, cubes and cassava meal which is in fine powder form. The refuse or waste is another product and the leaf meal which is the dried aerial part (or only leaves) of the cassava plant.

This study focuses attention on the cassava meal. The nutritive content of cassava meal varies according to variety, age and the processing technology.[34/, 46/] Cyanides are the most undesirable elements of the plant. The content varies between 0.01 to 0.24 percent in fresh tubers with the bitter varieties containing 0.02 - 0.03 percent and the sweet ones having less than 0.01 percent. Free hydrogen cyanide is liberated from the cyanogenetic glucosides by the action of the enzyme linamarase which is naturally present in the plant. Glucosides and linamarase come into contact only when the plant tissue is damaged.[7/, 20/]

The feeding of cassava to poultry dates back to 1935 when Tabayoyon[72/] incorporated a product derived from the extraction of cassava starch at the 30 and 60 percent levels into chicken diets. He found that feed consumption and 12-week body weight decreased as the level of the cassava by product in the diet increased. The next piece of work was in 1941 by McMillan and Dudley.[46/] They fed chicken diets containing 20 and 40 percent cassava root flour and did not notice deletirious effects on the health of the birds. However, they concluded that the higher level of substitution produced a reduction in weight gain.

Klein and Barlowen (1954) [36/] affirmed in their own study that cassava flour contained a factor that diminished feed consumption. They recommended that cassava flour should be used at levels not higher than 10 percent because higher levels were reported to decrease weight gain and feed efficiency.[67/] The works of Rendon, et al.[67/] confirmed the findings in 1969. These were also the views of Vogt and Penner in 1963 [74/] and in addition they expressed their findings that the adverse effects of high levels of cassava occur mainly in the first few weeks of life. Vogt [73/] (1966) therefore affirmed that broilers can consume cassava at levels higher than 10 percent only after the fourth week.

In 1964, Vogt and Stute [75/] observed that weight gains were higher with cassava pellets than with the meal, and that it is the excessively fine nature of the flour that influenced the feed intake negatively. Chou and Muller (1972) [12/] confirmed that cassava pellets could be used up to to 50 percent level without any adverse effect provided that the diets were duly balanced with regard to other nutrients. Other works which proved that the powdery nature of cassava flour decreases weight gains are those of Montilla, et al.[48]. The first one was in 1969. They incorporated [illegible], 15, and 30 percent sweet cassava root flour (sundried for about 36 hours) into chick rations. By the sixth week, they found decreases in both weight gains and feed efficiency as the cassava level increases in the rations.

In [illegible], [49] they advanced in their second study by using the same levels of substitution, and adding to all the diets, five percent animal fat and five percent sugar cane mollases with the view to eliminating the powdery nature of the rations. At the eighth week, they found that no significant differences in feed consumption and weight increase, or feed efficiency were detected between the treatments. Also, feed costs were reduced by 7.9 and [illegible] percent for the chicks which received rations containing 15 and [illegible] percent cassava. In 1975, [50] they carried out a third study which differs from the second only in the variety of cassava used. Rather than using the 'sweet' cassava, they used the 'sour' cassava root flour to replace the corn in the diet partially by [illegible] percent and totally by 37 percent of the ration. In both cases, sugar cane mollases and animal fat were used to replace 11 percent of the corn to eliminate the powdery nature. At the fourth week only the 37 percent cassava diet was significantly poorer. The authors attributed this to the [illegible] content of the cassava variety used.

It is pertinent to note that the cassava flour used in those experiments was merely sundried. The importance of methionine as a moderater of toxic effects of cassava products in poultry has been acknowledged by many authors.

Adegbola [1/] revealed that added methionine may be required to improve the quality and utilization of dietary protein and that even in a properly balanced diet, it may serve for the detoxication of prussic acid which is released in the hydrolysis of linamarin and loteustralin. He drew attention to the need to relate responses to added methionine in rations to the levels of protein in the diet as well as to the nature and palatability of the feed. He stressed that methionine shares its role with other sulfur-donors such as cystine, thiosulfate and elemental sulfur. Methionine is preferred because it is an essential amino-acid and when metabolised, it yields cystine and cysteine. The present study acknowledges these facts and provides for them by specifying certain levels of inclusion of those amino-acids in the diets.

Enriquez and Ross [17/] fed up to 50 percent cassava to poultry and observed consistent but not always significant improvement in body weight when the cassava was supplemented with 0.15 - 0.20 percent methionine. They concluded that when the ration was well balanced with protein and methionine, up to 50 percent cassava root meal satisfactorily replaced corn in the diet. Without methionine supplementation they found deterioration in weight gain at three weeks of age and significant differences in feed efficiency when cassava levels exceeded 20 percent. The addition of molasses and soybean oil had no beneficial effect, which proved according to the authors, that the problem was not one of palatability or essential fatty acid deficiency. The cassava used was harvested, washed, cut and dried for 24 - 40 hours in a grain drier at 50°C so that the flour had very low levels of HCN

Gadelha, et al. [24/] used 0, 15, 30 and 45 percent levels of cassava diets supplemented with 0.2 percent methionine. They observed that chicks gained weight more slowly and had a poorer feed conversion efficiency. The chicks also consumed less feed with increasing levels of cassava meal although the differences were not significant.

Obiora [53/] replaced the maize in broiler finisher rations with 'gari'(cassava processed in a different manner from cassava flour). He found that feed conversion efficiency was best with the feed containing'gari'and at the ratio of 29:24.5 percent for maize:'gari'ratio. He concluded that gari can replace all the maize in a broiler finisher diet or constitute up to 49 percent of the whole ration without any decrease in growth rate or carcass quality provided the ration is balanced for protein and amino-acids. Because cassava flour is sundried rather than roasted like gari, some minerals or vitamins might have been removed from the gari so that the performance of the birds with the use of cassava flour may prove better. He gave the best substitution level of gari as 50 percent or 29 percent of the whole ration.

Olson et al.[55] tested peeled cassava flour in broiler rations incorporating it in amounts from 7.5 - 45.0 percent, and making the rations isocaloric and isoproteinaceous by means of the addition of animal fat and soybean flour. Weight gain reduced as the amount of cassava flour increases although the differences were significant only at cassava levels from 37.5 - 45.0. They concluded that if the feed was balanced for energy and protein, cassava flour could be incorporated into chicks diet up to the 30 percent level without affecting weight increase.

Phuah and Hutagalung [65] tested rations with 19,22 and 25 percent levels of protein and 0, 20 and 40 percent levels of cassava flour on broilers from 3-6 weeks of age. After the sixth week, the protein levels of the diets were changed to 17, 20 and 23 percent. With 20 percent cassava, they found that the percentage carcass yield (dry basis) and carcass yield protein, were significantly higher and fat production was lower than that with cassava levels above 20 percent. When the cassava increased above the 20 percent level, digestibility of the protein was reduced and that of fat was increased.

Armas and Chicco (1973) [3] replaced corn in broiler diets with cassava flour at the 18, [illegible] and 54 percent levels. The diets were made to be isocaloric and isoproteinaceous. They found no significant differences in weight gains and feed efficiency although the diet with 54 percent cassava had a lower weight gain. The fact that the diets contained 8 or 16 percent animal protein, or were supplemented with 0.3 percent methionine and 0.3 percent lysine did not effect the results.

differences in their chemical composition caused by age, time of harvest and methods of processing.

5.5.3: Summary of Works on Cassava

The first pieces of work were on feeding of cassava refuse or meal to chicks and they were found to influence feed consumption negatively. Next, were efforts to eliminate the powdery characteristic of cassava meal as the factor affecting weight gains, by using animal fat and sugar molasses. The use of cassava pellets rather than the meal was also suggested by a couple of authors. Other factors in cassava believed to affect weight gains are the HCN content as well as the low protein content. Many studies were carried out in this respect by introducing 0.15 - 0.20 percent methionine as a moderator of toxic effects and by balancing the feed with respect to other nutrients such as amino-acids, energy and protein or by making the feed isoproteinaceous and isocaloric.

5.6 L.P. Solutions for the inclusion of cassava in starter diets

To determine the effect of including cassava on the cost and composition of starter diets, the L.P. model was designed to include cassava at the five percent level while providing a minimum of 24 and 26 levels of protein. Table 5.1 shows that there was an increase in feed cost of ₦54.35/ton in the diets having 24 percent protein whilst the increase in cost of the 26 percent protein diets was ₦53.87/ton. from the diet without cassava to diets with cassava. The differences in both cases represent 22 percent of the cost of diet with cassava. In the 24 percent protein diet, maize and guinea-corn provided the bulk of the energy whereas in the 26 percent protein diet, maize is excluded from the mix. Lysine was excluded from the 26 percent protein diets whereas dried yeast and groundnut cake were excluded from the 24 percent protein diets. In the 24 percent protein diets, the inclusion of cassava caused 7.4, 16.6, 54.9, 14.3, 53.5, 5.5, 54.0 percentage changes in oyster shell, maize, meat and bone, lysine, guinea-corn, methionine and bone-meal respectively. Changes in guinea-corn and maize, the energy-based ingredients are due to their substitution for the amount of cassava included. Changes in the synthetic amino-acids are due to the low content of these amino-acids present in cassava. Substitution in the mineral-based ingredients is to ensure that the specified levels are met in the correct proportion.

For the above reasons for changes in compositions, substitutions in the 26 percent protein diets occurred in oyster shell, meat and bone, guinea-corn, bone-meal, dried yeast and groundnut cake. The percentage changes were 7.4, 61.8, 11.1, 21.9, 51.6 and 7.0 respectively.

Both rations provided the essential nutrients at the levels specified for the broiler starter rations. The level of inclusion of synthetic methionine ranges between 0.15 - 0.19 and this is consistent with the levels specified in the studies reviewed above.

TABLE 5.1: The effect of including cassava on the cost and composition of starter ration – U.I. prices

Ingredients and Nutrients	Percentage Composition					
	Minimum Protein 24%			Minimum Protein 26%		
	With Cassava	Without Cassava	% Change	With Cassava	Without Cassava	% Change
Brewer's grains	5.00	5.00	--	5.00	5.00	--
Soyabean	30.00	30.00	--	30.00	30.00	--
Oyster shell	2.16	2.32	7.4	2.32	2.49	7.4
Maize	28.64	23.59	16.6		--	--
Meat and Bone	2.20	1.01	54.9	2.[illegible]	1.32	51.8
Syn. Lysine	0.07	0.08	14.3	--	--	--
Guinea-corn	20.18	30.88	53.5	45.11	50.34	11.1
Syn. Methionine	0.18	0.19	5.5	0.15	0.15	--
Bone meal	0.66	1.[illegible]	54.0	0.22	0.70	21.9
Salt	0.30	0.30	--	0.30	0.30	--
Wheat Bran	5.00	5.00	--	5.00	5.00	--
Ad Vit	0.60	0.60	--	0.60	0.60	--
Cassava	5.00	--	--	5.00		--
Dried Yeast	--	--	--	0.60	1.03	51.6
G. nut cake	--	--	--	2.86	3.06	7.00
Cost of 1 ton of mix	₦253.69	₦199.34	22.00	₦241.68	₦187.81	22.5
Protein	24	24	--	26	26	--
Fibre	4.1	4.0	1.74	4.5	4.6	2.2
Fat	5.0	5.0	--	5.0	5.0	--
Calcium	1.5	1.5	--	1.5	1.5	--
Lysine	1.25	1.25	--	1.25	1.25	--
Methionine	0.50	0.50	--	0.50	0.50	--
Phosphorus	0.80	0.80	--	0.80	0.80	--
Cystine	0.32	0.33	3.12	0.34	0.35	2.94
Tryptophan	0.27	0.28	4.00	0.30	0.31	3.33
Energy (kcals./kg)	3,639	3,620	0.5	3,567	3,562	0.1

5.7 The Composition and costs of starter diets with varying prices of cassava

Some measures were discussed earlier in section 5.4 that could make cassava products available in large abundant quantities and at low prices too. These measures include the incorporation and adaptation of research findings into peasant and large scale farming systems. Also, more efforts should be put into research as regards the development of high yielding varieties of cassava and better agronomical practices and processing techniques. Decreases in the prices of cassava are therefore envisaged in future and this is the reason for using lower prices of cassava in order to view the effects of lower cassava prices on the costs and compositions of the diets.

In parameterising with prices, the model was designed to allow cassava to come freely into the mix within the range of 0-30 percent. The different prices of cassava used are ₦125, ₦150, ₦175, ₦200, ₦225 and ₦250 per tonne. These prices are lower than the existing price of cassava used in the basic solution which is ₦320/tonne. In the solutions, it is expected that cassava should substitute for guinea-corn and maize in varying proportions. This is because the prices of maize and guinea-corn differ; so are their nutrient compositions. Maize costs [illegible] per tonne whereas the price of guinea-corn is ₦220 per tonne.

Table 5.2 shows the costs and compositions of starter diets when varying prices of cassava are used in the programming exercises.

TABLE 5.2: The composition and costs of starter diets with varying prices of cassava

Ingredients	Cassava replacing G. Corn			Cassava replacing Maize		
	PRICES OF CASSAVA					
	₦125	₦150	₦175	₦125-150⁺	₦175	₦200⁺⁺ ₦225 ₦250
Cassava	30.00	27.14	--	[illegible]	2[illegible].94	13.37
Guinea-corn	14.64	17.89	65.36	--	--	--
Maize	--	--	--	14.55	18.[illegible]	36.97
Brewer's grains	4.31	5.00	5.00	4.27	5.00	5.00
Synthetic Methionine	0.22	0.22	0.24	0.22	0.23	0.24
Blood meal	--	0.24	7.[illegible]	[illegible]	1.23	5.93
Syn. Lysine	0.28	0.27	-	[illegible]	[illegible].21	-
Palm kernel meal	15.00	15.00	15.00	15.00	15.00	15.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
G. nut cake	30.00	30.00	12.27	30.00	30.00	20.41
Ad Vit	0.60	[illegible]	0.60	0.60	0.60	0.60
Meat & Bone scrap	4.60	5.35	3.56	4.04	2.50	2.17
Wheat Offals	--	--	0.54	--	--	0.01
COST OF FEED/TONNE						
	₦178.60	₦180.04	₦191.65	₦180.36 ₦187.86	₦194.94	₦199.93 ₦203.28 ₦206.62

⁺ The mix of ingredients remains the same for prices of cassava at ₦125 and ₦150 per tonne but the costs of the feeds vary. When cassava price was fixed at ₦125/tonne the feed costs ₦180.36 and with cassava price fixed at ₦150/tonne the feed costs ₦187.86.

⁺⁺ Optimum solution remains the same for a range of prices of cassava from ₦200-₦250. However, the costs of the feed are ₦199.93, 203.28, ₦206.62 for cassava prices of ₦200, ₦225 and ₦250 per tonne respectively.

5.7.1: Substitution Between Maize and Cassava

At cassava prices of ₦200, ₦225 and ₦250 per tonne, the solution remains the same but with varying costs of ₦199.93, ₦203.28, ₦206.62 per tonne respectively. Cassava was included up to 13 percent level only. When the price of cassava was lowered to ₦175 per tonne, the mix included cassava at a higher level of 27 percent whilst the cost of the feed reduced to ₦194.94 per tonne. At cassava prices of ₦125 and ₦150 per tonne, the optimum mix remains the same with the cost of feed falling to ₦190.36 and ₦187.86 per tonne. Cassava however, comes into the solution at the maximum level of 30 percent.

5.7.2: Substitution Between Guinea-corn and Cassava

The solutions with respect to the compositions and costs of feed differ however, if substitution is between cassava and guinea-corn rather than maize. Cassava does not come into the optimum mix if its cost is higher than ₦150 per tonne. At the price of ₦150 per tonne, cassava comes into the solution at the 27 percent level and at ₦125 per tonne, it comes into the mix at the maximum level of 30 percent. The costs of the feed increase as the price of cassava increases.

5.8: Feeding Trials

As stressed earlier in chapter four, the least-cost diet is not necessarily the least-time or the most efficient diet. Also it may not be the diet that gives the maximum net profit. In the previous sections, cassava has been made to replace maize and guinea-corn in the diets. It is therefore very important to measure the responses of birds to such cassava based diets as done in the earlier studies reviewed. Feeding trials were carried out also to clarify the notion that cassava-based diets usually depress growth and if in fact it does, whether it is uneconomical to use it. One other objective is to compare the computerised diets with two commonly used commercial diets.

5.8.1: Experimental diets

In formulating the experimental diets, the existing price of cassava of ₦320 per tonne was used.

A total of 14 starter and 10 finisher diets were computerised for the experiments. It was the objective in the formulation of the starter diets to have 0, 5, 10, 15, 20, 25 and 30 percent cassava replace guinea-corn and maize respectively. These levels of cassava were given equality restraints so as to ensure that cassava is included at the exact levels in the various diets. This is because the cost of cassava is so high that it does not come in freely into the mix if given a minimum or maximum constraint, and if it comes in at all, it does not enter at the exact integer levels specified.

(a) Cassava replacing guinea-corn (Starters): The solution with regard to cassava replacing guinea corn is presented in Table 5.3. The mix changed as the cassava level increased in the diets. Because of the

TABLE 5.3: Composition and costs of starter diets with cassava substituting for guinea-corn.

Ingredients and Nutrients		GCC 1	GCC 2	GCC 3	GCC 4	GCC 5	GCC 6	GCC 7
Cassava		0	5.00	10.00	15.00	20.00	25.00	30.00
Guinea-corn		55.36	49.16	42.09	35.03	27.97	20.91	14.64
Brewer's grains		5.00	5.00	5.00	5.00	5.00	5.00	4.31
Syn. methionine		0.24	0.23	0.23	0.23	0.22	0.22	0.22
Blood Meal		7.13	6.30	4.93	3.56	2.19	0.82	--
Palm kernel meal		15.00	15.00	15.00	15.00	15.00	15.00	15.00
Salt		0.30	0.30	0.30	0.30	0.30	0.30	0.30
Ground nut cake		12.27	14.05	17.65	21.25	24.86	28.46	30.00
Ad Vit		0.60	0.60	0.60	0.60	0.60	0.60	0.60
Wheat Bran		0.54	--	--	--	--	--	--
Meat & Bone scrap		3.56	4.33	4.11	3.89	3.67	3.44	4.66
Synthetic Lysine		-	0.03	0.09	0.14	0.20	0.25	0.28
Tryptophan		0.23	0.23	0.24	0.25	0.25	0.26	0.26
Fibre		4.65	4.56	4.54	5.03	4.52	5.00	4.36
Fat		4.50	4.50	4.50	4.50	4.50	4.50	4.50
Calcium		0.07	0.81	0.82	0.82	0.83	0.84	1.03
Lysine		1.25	1.25	1.25	1.25	1.25	1.25	1.25
Methionine		0.51	0.50	0.50	0.50	0.50	0.50	0.50
Phosphorus		0.72	0.75	0.74	0.72	0.73	0.69	0.77
Cystine		0.20	0.27	0.27	0.27	0.27	0.26	0.25
Protein		24.00	24.00	24.00	24.00	24.00	24.00	24.00
Energy		2900	2900	2900	2900	2900	2900	2900
Cost of one	₦320		199.10	206.57	214.04	221.51	228.98	237.10
ton of feed	₦270		196.60	201.37	206.54	211.51	216.48	222.10
with these	₦220		194.10	196.57	199.04	201.51	203.93	207.10
prices of	₦170		191.60	191.57	191.54	191.51	191.48	192.10
cassava	₦120		189.10	186.57	184.04	181.51	178.98	177.10

+GCC 1-7 indicate starter diets in which cassava replaced guinea corn as the major energy source.

low protein content of cassava, the groundnut cake level increased with increases in the cassava level. When cassava increased from 0 to 5 percent, groundnut cake increased by 1.78 percent. For every other 5 percent cassava increase up to 25 percent level, there was a 3.6 percent increase in the groundnut cake level. The last 5 percent increase in cassava up to the 30 percent level produced only an increase of 1.5 percent in the groundnut cake level. The reverse was the situation with Blood meal. Decreases in the blood meal level were the same for the first and last addition of 5 percent cassava into the diet. Increasing cassava from 0 to 5 percent and 25 to 30 percent each resulted in a decrease of 0.82 and 0.83 percent respectively. However, the addition of 5 percent cassava up to the 25 percent level resulted in a constant increase of 1.37 percent of blood meal. Such was the pattern of change in the levels of meat and bone scrap. To balance the amino-acid contents of the diets, synthetic lysine levels increased in the diets at an average of 0.06 percent for every 5 percent increase in cassava. For the first and last 5 percent increase in cassava, guinea-corn fell by 6.2 percent and successive 5 percent increase up to 25 percent, there was a decrease of 7.06 percent in the guinea-corn level. The rate of substitution is 0.74. The costs of the diets increased as the cassava level increased.

(b) Cassava replacing maize (starters): The solution with regard to cassava replacing maize in the diet is presented in Table 5.4. The

TABLE 5.4: Composition and costs of starter diets with cassava replacing maize in the diets

Ingredients and Nutrients	MC1	MC2	MC3	MC4	MC5	MC6	MC7
Cassava	0	5.00	10.00	15.00	20.008	25.00	30.00
Maize	55.77	49.11	41.86	34.57	27.23	20.07	14.55
Brewer's grains	3.63	4.37	4.75	5.00	5.00	5.00	4.27
Syn. Methionine	0.26	0.25	0.25	0.24	0.24	0.23	0.22
Blood Meal	10.50	8.07	7.12	5.30	3.22	1.47	0.80
Palm kernel Meal	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Groundnut cake	11.97	13.87	17.77	21.81	26.09	30.00	30.00
Ad- Vit	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Wheat Bran	–	–	–	0.08	0.30	0.41	–
Meat & Bone scrap	2.19	2.63	2.35	2.08	1.80	0.20	0.23
Synthetic Lysine	–	–	–	0.03	0.12	0.20	0.23
Bone Meal	0.20	–	–	–	–	–	–
Tryptophan	0.22	0.22	0.23	0.24	0.25	0.26	0.25
Fibre	3.45	3.63	3.80	3.97	4.11	4.24	4.11
Fat	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Calcium	0.60	0.60	0.60	0.60	0.60	0.62	0.95
Lysine	1.42	1.38	1.30	1.25	1.25	1.25	1.25
Methionine	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Phosphorus	0.61	0.60	0.59	0.57	0.56	0.57	0.91
Cystine	0.29	0.28	0.26	0.28	8.20	0.28	0.26
Protein	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Energy	2900	2900	2900	2900	2900	2900	2900
Cost of one ton N320		211.38	214.12	216.13	224.75	231.37	238.86
of feed with N270		206.88	209.12	210.63	214.75	218.87	223.86
those prices of N220		205.38	204.12	203.13	204.75	206.37	208.86
cassava per ton N170		203.88	199.12	195.53	194.75	193.87	193.86
N120		201.38	194.12	188.13	184.75	181.37	178.86

MC1–7 represent starter diets in which cassava replaced part of the maize as the major energy source.

groundnut cake level increased here too with increasing cassava levels to make up for the low protein content of cassava. For 25 and 30 percent cassava levels there was no increase in groundnut cake level because the maximum quantity allowed was included at the 25 percent level of cassava. For increase of cassava from 0 to 5 percent, there was 1.9 percent increase in groundnut cake and for subsequent 5 percent increases in cassava up to the 25 percent level there was an average increase of about 4 percent in the groundnut cake level. The pattern of decrease was the same in the blood meal levels as cassava levels increased. The increase from 0-5 percent in cassava resulted in 1.13 percent decrease in blood meal. Subsequent 5 percent increases in cassava up to 25 percent level resulted in an average of about 1.8 percent decrease in blood meal. The increase in cassava from 25 to 30 percent resulted in 0.67 percent decrease in blood meal. Lysine was introduced into the mix at the 15 percent level of cassava at 0.03 percent increasing to 0.26 percent in the 30 percent cassava diet, to make up for the low lysine content of cassava.

Substitution in the energy based ingredient resulted in a substitution rate of 0.73. The first 5 percent cassava increase resulted in a decrease of 6.56 percent in the maize content. Subsequent increases in cassava up to the 25 percent level resulted in an average of 7.3 percent decrease. The last addition of cassava from 25 to 30 percent resulted in a 5.52 percent decrease in maize level. The costs of the diets also increased as the cassava level increased in the diets.

(c) Cassava Replacing Guinea-corn (Finishers): Table 5.5 gives the composition of the finisher diets in which cassava replaced guinea-corn at varying levels from 0 to 40 percent. In the finisher diets, the cassava levels were increased to 35 and 40 percent levels. Equality restraint was also used so that the stated levels were included in the diets. These are shown in Tables 5.5 and 5.6. Changes in the protein components of the feed were very minor. Groundnut cake was included in the ration as from 20 percent cassava level. Increases were 0.99 percent with each 5 percent increase in cassava level. Increase from 35 percent to 40 percent cassava results in a 3.1 percent increase in groundnut cake. The maximum level of groundnut cake in the diet being 7.71 percent. This low level of groundnut cake was however compensated for in the diets which took up Blood meal at the maximum level permitted.

In the energy based ingredients, the rate of substitution of cassava for guinea-corn was 0.81. With each 5 percent increase in cassava level, there was a decrease of about 5 percent in the level of guinea-corn in the diets. Slight variations occurred in the mineral components such as bone meal and oyster shell. Lysine was completely excluded and other ingredients remained constant. The costs of the feed increased as the cassava level increased.

(d) Cassava Replacing Maize (Finishers): The composition and cost of diets in which Cassava partially replaced maize appear in Table 5.6. Slight changes occurred in the protein components of the feed. For

TABLE 5.5: Composition and costs of finisher diets with cassava replacing guinea-corn

Ingredients Nutrients Prices		GCC 8	GCC 9	GCC 10	GCC 11	GCC 12	GCC 13	GCC 14	GCC15	GCC
Cassava		0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.09	40.0
Guinea-corn		56.21	50.51	44.86	39.2[illegible]	[illegible]	26.33	20.18	14.05	6.5
Palm kernel meal		15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.0
Oyster shell		0.51	0.44	0.40	0.36	0.25	0.35	0.44	0.54	0.4
Dried Yeat		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.0
Bone Meal		1.35	1.42	1.48	1.55	1.59	1.[illegible]	1.71	1.76	1.7
Brewer's grains		5.12	5.68	6.22	6.77	7.00	7.00	7.00	7.00	7.0
Wheat Bran		7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.0
Salt		0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.3
Ad Vit		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.5
Blood Meal		9.70	9.92	10.00	10.00	10.00	10.00	10.00	10.00	9.47
G. nut cake		--	--	--	--	1.65	2.64	3.62	4.61	7.71
Synthetic Meth.		0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.25	0.24
Calcium		0.81	0.84	0.88	0.92	0.93	1.02	1.11	0.80	1.20
Tryptophan		0.28	[illegible]	0.19	0.20	0.20	0.20	0.20	0.20	0.20
Fibre		5.00	[illegible]	5.00	5.00	4.98	4.91	4.84	4.77	4.74
Protein		21.02	[illegible]	20.45	20.10	20.33	20.24	20.16	20.10	20.50
Phosphorus		0.80	[illegible]	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Fat		3.7[illegible]	[illegible]	3.50	3.40	3.34	3.23	3.14	4.04	3.02
Methionine		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Cystine		0.29	0.29	0.28	0.27	0.27	2.27	0.27	0.2[illegible]	0.26
Lysine		1.30	[illegible]	1.30	1.29	1.20	1.30	1.30	1.30	1.30
Energy		2800	2800	2800	2800	2800	2800	2800	2800	2809
Cost of one ton of feed with cassava prices stated.	₦320	175.29	179.16	183.[illegible]	187.[illegible]	191.36	196.02	200.69	205.35	210.2
	₦270		176.65	17[illegible].09	179.51	181.3[illegible]	183.52	185.69	187.85	190.2
	₦220		174.16	173.09	172.[illegible]	171.36	171.02	170.69	170.35	170.2
	₦170		171.66	168.09	164,51	161.36	158.52	155,69	152.85	150.2
	₦120		169.1[illegible]	163.09	157.01	151.36	146.02	140.69	135.35	130.2

GCC8--16 denotes the finisher diets in which cassava partially replaced guinea-corn in the diet.

TABLE 5.6: Composition and costs of finisher diets with cassava replacing maize

Ingredients Nutrients Prices		MC 8	MC 9	MC10	MC11	MC12	MC13	MC14	MC15	MC16
Cassava		–	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
Maize		53.81	48.02	41.84	33.44	27.17	21.[illegible]	14.64	8.68	2.52
P-kernel meal		15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Oyster shell9		0.06	–	–	–	–	–	–	–	–
Dried Yeast		–	–	–	–	–	0.53	1.40	2.22	3.04
Bone Meal		1.76	1.73	1.[illegible]	1.50	1.73	1.[illegible]	1.77	1.75	1.72
Brewer's grains		5.18	6.15	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Wheat Bran										
Salt		0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Ad Vit		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Blood Meal		9.69	9.07	9.98	9.15	9.20	9.05	8.83	8.52	8.25
G. nut cake		6.41	8.14	7.08	10.84	11.82	12.52	13,15	13,80	14.43
Syn. methionine		0.23	0.20	0.28	0.27	0.27	0.26	0.25	0.24	0.24
Calcium Methion.		0.80	0.[illegible]	0.80	0.80	0.91	0.92	1.00	1.01	1.04
Tryptophan		0.18	0.18	0.16	0.20	0.21	0.20	0.21	0.22	0.23
Fibre		4.24	4.40	4.54	4.66	4.70	4.72	4.75	4.78	4.81
Protein		21.27	21.20	21.20	21.96	22.00	22.00	22.00	22.00	22.00
Phosphorus		0.80	0.80	0.77	0.75	0.80	0.80	0.80	0.80	0.80
Fat		4.22	4.10	4.00	4.00	3.87	3.73	3.58	3.44	3.30
Methionine		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cystine		0.29	0.29	0.29	8.29	0.29	0.29	0.29	0.28	0.28
Lysine		1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Energy		2800	2800	2800	2800	2800	2800	2800	2800	2800
Cost of 1 ton of feed with these prices of cassava	₦320	193.48	194.99	196.64	198.96	201.49	204.04	206.60	209.15	211.70
	₦270		192.49	191.64	191.46	191.49	191.54	191.60	191.65	191.70
	₦220		189.99	186.54	183.96	181.49	179.04	176.30	174.15	171.70
	₦170		187.49	181.64	176.46	171.49	166.54	161.60	156.65	151.70
	₦120		184.99	176.64	168.96	161.49	154.04	146.60	139.15	131.70

each 5 percent increase in the cassava level, blood meal decreased by 0.18 percent. From 10 to 15 percent cassava level, the decrease is 0.75 percent in blood meal. From 30 percent up to 40 percent cassava level, decreases are about 0.25 percent. For groundnut cake, there was no discernible pattern of increase as the cassava levels increased. However, from 0-40 percent cassava levels, the groundnut cake levels of inclusion varied from 6.41 to 14.43 percent.

Slight changes occurred in the mineral components such as bone meal and dried yeast. Dried yeast was eliminated from the diets with 0-20 percent cassava. Oyster shell was also excluded from the mix for all cassava based diets. The rate of substitution of cassava for maize was 0.78 with decreases of about 0.2 percent in the maize component for every increase in the cassava level. Slight changes occurred in the methionine levels whereas synthetic lysine was excluded completely. The costs of the diets increased as the cassava level increased.

5.9 Experimental

Four consecutive experiments were carried out using broiler chickens of the cobb strain. The first two experiments (experiments IIIand IV) involved trials with starter chicks (0-6 weeks), while the last two experiments (V and VI) involved finishers (6-12 weeks).

In the first two experiments, birds were randomly distributed in the pens such that each pen had 30 birds. Each diet had four replicate groups of 30 birds making a total of 120 birds per diet.

In the experiment III, diets GCC1 - GCC7 were computer formulated such that cassava flour partially replaced guinea-corn at varying levels of 0, 5, 10, 15, 20, 25 and 30 percent respectively. Two commercial diets denoted commercial I and III were also used for comparison. The composition of the linear programmed diets used in this trial appear in Table 5.3.

In experiment IV, the set up was exactly the same as in experiment III except that the diets were programmed in such a way that cassava flour replaced maize rather than guinea-corn in the test diets. The compositions of the diets used in this experiment are given in Table 5.4. Also a differênt commercial diet was used instead of commercial II in this experiment and is accordingly denoted as commercial III.

Experiment V and VI compared the responsiveness of birds to various finisher diet in which cassava replaced guinea-corn at levels 0, 5, 10, 15, 20, 25, 30, 35 and 40 percent (Experiment V) or maize at the same levels (Experiment VI). In each of these experiments two commercial finisher diets I and III were used as standards against which the linear programmed diets were compared. The birds used were also Cobb broilers which were randomised into pens such that there were 20 birds per pen. There were four replicates per diet giving a total of 80 birds per diet.

In all of the above experiments, weekly records of change in body weight and feed consumption were kept. Records of daily mortality were also kept.

5.9.1: Statistical analysis of data

Results

(a) Experiment III

The results for this are presented in Table 5.7. The technique of analysis of variance was used on columns 3-5 of Table 5.7 (See Anova tables 5.7.1 - 5.7.3) which show that there were no significant ($P < 0.05$) differences between the average weight gains and average feed intake, but there were for feed conversion efficiency for the birds on each diet. To detect the treatments causing these significant ($p < 0.05$) differences in only the feed conversion efficiency, the criterion of least significant difference was used.

It was discovered that diets GCC 4, GCC 5 and GCC 7 were causing the differences. These diets performed poorest in terms of FCE. However, pairing the diets and comparing them showed that significant ($P < 0.01$) differences occurred between diets GCC 1 and GCC4, GCC1 and GCC5, GCC1 and GCC7, then GCC2 and GCC5, GCC2 and GCC7, GCC3 and GCC4, GCC3 and GCC5, GCC3 and GCC7. Other significant differences occurred between diets GCC4, GCC5 and GCC7 and commercial diets I and III.

(b) Experiment IV

The results are summarised in Table 5.8.

TABLE 5.7: Performance comparisons of starter diets in which guinea-corn is replaced by 0 - 30 percent of cassava

1 Diets+	2 Cassava Levels	3 Average Weight gain (kg)	4 Average Feed Intake (kg)	5 Feed/Weight Feed Conversion Efficiency F.C.E.
GCC 1	0	0.674	1.58	2.34
GCC 2	5	0.562	1.47	2.62
GCC 3	10	0.663	1.60	2.41
GCC 4	15	0.587	1.68	2.86
GCC 5	20	0.557	1.65	2.98
GCC 6	25	0.613	1.60	2.61
GCC 7	30	0.484	1.46	3.02
Commercial I	-	0.665	1.72	2.59
Commercial III	-	0.752	1.74	2.31
Mean	-	0.62	1.61	2.64
Standard Error	-	0.0787	0.0997	0.2655

+Composition of diets are in Table 5.3.

Table 5.7.1: ANOVA Table for Weight Gains

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05\,(8,24)}$ / $F_{0.01\,(8,\,24)}$
Treatment	0.20	8	0.025	2.27	2.36
Blocks	0.80	3	0.27		3.36
Error	0.26	24	0.011		
Total	1.26	35			

Table 5.7.2: ANOVA Table for Feed Intake

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05(8,\,24)}$ / $F_{0.01(8,\,24)}$
Treatment	0.306	8	[illegible]	2.0	2.36
Blocks	3.103	3	[illegible]		3.36
Error	[illegible].452	24	0.019		
Total	3.861	35			

Table 5.7.3: ANOVA Table for Feed Conversion Efficiency

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F	$F_{0.05(8,24)}$ / $F_{0.01(8,\,24)}$
Treatment	6.594	8	[illegible]	3.169*	2.36
Blocks	2.39	3	[illegible].299		3.36
Error	6.241	24	[illegible].26		
Total	15.225	[illegible]			

*Significant at P < [illegible].

TABLE 5.8: Performance comparisons of starter diets in which cassava (0 - 30 percent) replaced maize in the diets

1 +Diets	2 Cassava Levels	3 Average Weight gain (kg.)	4 Average Feed Intake (kg.)	5 Feed/Weight Feed Conversion Efficiency F.C.E.
MC 1	0	0.611	1.66	2.42
MC 2	5	0.571	1.74	2.59
MC 3	10	0.642	1.65	2.57
MC 4	15	0.654	1.65	2.48
MC 5	20	0.574	1.56	2.72
MC 6	25	0.600	1.64	2.73
MC 7	30	0.525	1.48	2.81
Commercial I	-	0.665	1.72	2.59
Commercial III	-	0.752	1.74	2.31
Mean	-	0.633	1.65	2,72
Standard Error	-	0.0475	0.085	0.502

+Compositions of diets are in Table [illegible]

Table 5.8.1: ANOVA Table for weight gains

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	F	$F_{0.05(8,24)}$ $F_{0.01(8,24)}$
Treatment	0.31	8	0.[illegible]	7.8**	2.36
Blocks	0.36	3	0.12		3.36
Error	0.12	24	0.005		
Total	0.79	35			

Table 5.8.2: ANOVA Table for Feed Intake

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F	$F_{0.05(8,24)}$ $F_{0.01(8,24)}$
Treatment	0.22	[illegible]	0.0275	2.308	2.36
Blocks	2.554	[illegible]	0.851		3.36
Error	0.286	24	0.012		
Total	3.06	35			

Table 5.8.3: ANOVA Table for Feed Conversion Efficiency

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F	$F_{0.05(8,24)}$ $F_{0.01(8,24)}$
Treatment	[illegible].495	8	0.937	7.94**	2.36
Blocks	0.715	3	0.23[illegible]		3.36
Error	2.83	24	0.118		
Total	11.04	35			

**Significant at P ≤ 0.[illegible]

Analysis of variance technique was used on columns 3-5 of Table 5.8 (See ANOVA Tables 5.8.1 - 5.8.3) which showed that there were significant ($P < 0.05$) differences between the average weight gains, and feed conversion efficiency for the birds on each diet. The criterion of lsd was used to detect the treatments causing the differences. In the weight gained by birds, significant ($P < 0.01$) differences occurred mainly with diets MC 6 and MC 7 and commercial III when compared with the other diets. Diets MC 6 and MC 7 performed poorest whilst commercial III diet was best.

Comparing the FCE of the birds for each diet, significant ($P < 0.01$) differences were caused by diets MC 5, MC 6 and MC 7 which were the poorest and then commercial III diet which was the best.

(c) Experiment V

The results of the experiment are summarised in Table 5.9. Analysis of variance technique used on columns 3-5 of Table 5.9 are summarised in ANOVA Tables 5.9.1 - 5.9.3. The tests showed that significant ($P < 0.05$) differences occurred only in the feed conversion

TABLE 5.9: Performance comparisons of finisher diets in which 0-40 percent cassava replaced guinea-corn in the diets

1 +Diets	2 Cassava Levels	3 Average Weight gain (kg.)	4 Average Feed Intake (kg.)	5 Feed/Weight Feed Conversion Efficiency FCE
GCC 8	0	1.04	4.543	4.363
GCC 9	5	0.805	4.555	5.650
GCC 10	10	0.966	4.493	4.651
GCC 11	15	0.857	4.237	4.944
GCC 12	20	0.879	4.600	5.233
GCC 13	25	0.840	4.407	5.246
GCC 14	30	0.727	4.788	6.586
GCC 15	35	0.805	4.691	5.827
GCC 16	40	0.732	4.634	6.330
Commercial I	-	0.927	4.177	4.498
Commercial III	-	1.130	4.235	3.651
Mean	-	0.886	4.467	5.181
Standard Error	-	0.134	0.208	0.880

+Compositions of diets are in Table 5.5.

Table 5.9.1: ANOVA Table for Weight Gains

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05(10,30)}$ $F_{0.01(10,30)}$
Treatment	0.58	10	0.058	1.16	2.16
Blocks	0.25	3	0.083		2.98
Error	1.64	30	0.05		
Total	2.37	43			

Table 5.9.2: ANOVA Table for Feed Intake

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05(10,30)}$ $F_{0.01(10,30)}$
Treatment	1.301	10	0.130	2.06	2.16
Blocks	27.421	3	9.14		2.98
Error	1.990	30	0.067		
Total	30.80	43			

Table 5.9.3: ANOVA Table for Feed Conversion Efficiency

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F	$F_{0.05(10,30)}$ $F_{0.01(10,30)}$
Treatment	41.332	10	4.133	2.275*	2.16
Blocks	1.787	3	0.596		2.98
Error	54.515	30	1.817		
Total	97.635	43			

*Significant at $P < 0.05$.

efficiency of the birds on each diet. To determine the diets causing the significant ($P < 0.01$) differences in FCE of the birds on these diets, the lsd statistic test was performed. Significant differences occurred mainly with diets GCC 12, GCC 14 GCC 16 and commercial III when compared with the other diets. Diets GCC 14 and GCC 16 performed poorest whilst diets GCC 12 and commercial III were best.

(d) Experiment VI

The results are summarised in Table 5.10. Analysis of variance technique used on columns 3-5 of Table 5.10 are summarised in ANOVA Tables 5.10.1 - 5.10.3. The tests showed significant ($P < 0.01$) differences in the average weight gains and F C E of the birds on each diet. The lsd statistic test showed that the diets causing the significant ($P < 0.01$) differences in the average weight gains and feed conversion efficiency of the birds are MC 14, MC 15 and MC 16 which performed poorest. So also did commercial III diet which performed best in terms of weight gains and feed conversion efficiency.

5.9.2: Conclusions

The results of the experiments indicated significant ($P < 0.01$), ($P < 0.05$) differences in the Feed Conversion Efficiency of the birds.

TABLE 5.10: Performance comparisons of finisher diets in which 0-40 percent cassava replaced maize in the diets

1 + Diets	2 Cassava Levels	3 Average Weight gain (kg.)	4 Average Feed Intake (kg.)	5 Feed/Weight Conversion Efficiency (F.C.E.)
MC 8	0	0.890	4.438	4.99
MC 9	5	0.837	4.768	5.70
MC 10	10	0.856	4.632	5.49
MC 11	15	0.892	4.671	5.24
MC 12	20	0.974	4.586	4.84
MC 13	25	0.953	3.890	4.08
MC 14	30	0.483	3.448	7.14
MC 15	35	0.550	3.320	6.04
MC 16	40	0.540	3.368	6.27
Commercial I	-	0.929	4.179	4.50
Commercial III	-	1.160	4.235	3.65
Mean	-	0.824	4.141	5.03
Standard Error	-	0.211	0.547	1.04

+Compositions of diets are in Table 5.6

Table 5.10.1: ANOVA Table for Weight Gains

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05(10,30)}$ $F_{0.01(10,30)}$
Treatment	1.55	10	0.155		2.16
Blocks	0.06	3	0.02	3.039**	2.98
Error	1.53	30	0.051		
Total	3.14	43			

Table 5.10.2: ANOVA Table for Feed Intake

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	$F_{0.05(10,30)}$ $F_{0.01(10,30)}$
Treatment	0.847	10	0.085		2.16
Blocks	10.371	3	3.457	1.746	2.98
Error	15.216	30	0.507		
Total	34.434	43			

Table 5.10.3: ANOVA Table for feed Conversion Efficiency

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F	$F_{0.05(10,30)}$ $F_{0.01(10,30)}$
Treatment	100.068	10	10.007		2.16
Blocks	25.227	3	8.409	9.687**	2.98
Error	30.975	30	1.033		
Total	156.270	43			

**Significant at P < 0.01.

As regards weight gains, significant ($P < 0.01$) differences were found only in starter and finisher diets in which cassava replaced maize.

In all the diets (starter and finisher) differences could be observed in the average weight gains, feed intake and feed conversion of the birds although the areas where these differences have been significant were highlighted above. The diets causing significant differences were the diets that performed poorest which were those in which the cassava contents were very high (25 - 40 percent). In formulating these diets, the fat content was constant and there was no addition of supplementary fat or oil to reduce the powdery nature caused by high cassava content (Voght and Stute[25/] (1934), Chou and Muller[12/] (1972), Montilla, et al [49/] (1969). This powdery nature of the diets reduced feed intake of the birds. This in turn reduced the nutrient intake and consequently led to reduced growth rate.

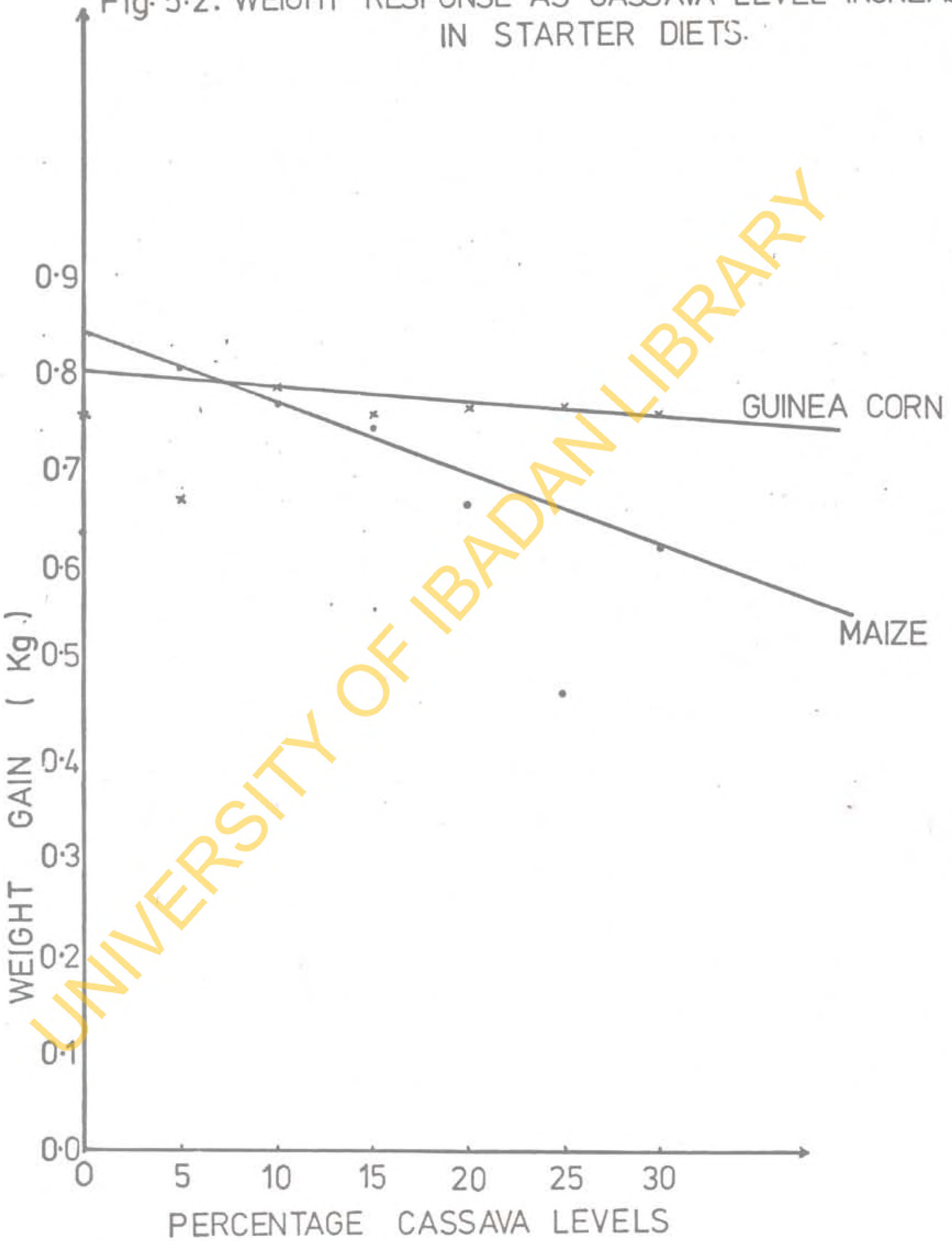
In the diets where there were no significant differences in weight gains (starter and finisher diets in which cassava replaced guinea-corn), there is an indication that nutrients were equally available to the birds in adequate and almost the same quantities because the diets were compounded to be nutritionally balanced. The main differences would then be in the returns over feed costs for each of the diets. This is estimated in the next chapter.

Although, growth is suppressed according to the nation of various authors, it is pertinent to note that even the diet with 40 percent level of cassava is still highly tolerable to the birds.

5.10 Weight response as Cassava level increased

The notion that has been held to this time is the fact that higher levels of cassava in the feed impairs growth rate. The same has been observed in the series of experiments performed in this study as shown in Figure 5.2. The diets were balanced nutritionally with amino acids as suggested by Chou and Muller [12] as well as with the other nutrients. The diets also came out to be isoproteinaceous and isocaloric as suggested by various authors (Armas and Chicco,[3] Olson, et al.[57] (1969). These authors concluded that up to 50 percent cassava could be used for chicks without any deleterious effects. Other factors which could be responsible for decreasing weight gains are therefore, the HCN contents of the cassava used, (Adegbola [1], Enriquez and Ross [17], Klein and Barlowen [36], Montilla, et al [50] (1975) and the powdery characteristic nature of cassava, (Chou and Muller [12], Vogt and Stute [75], Rendon et al [67], Montilla, et al [49] (1970). All the authors with the notion that it is the HCN and powdery nature of cassava that affects growth suggest the use of cassava at levels higher than 15 percent only after the fourth week. Since other authors (Adegbola, Gadelha, et al.) have proved methionine as a moderator of toxic effects, the only factor left in the experiments in this study is

Fig. 5.2: WEIGHT RESPONSE AS CASSAVA LEVEL INCREASES IN STARTER DIETS.



the powdery nature of the diets influenced by higher levels of cassava flour in the diets. The method of making the feed into pellets or the cassava into pellets has been found to improve the performance of the diets (Vogt and Stute [75], Rendon, et al [67], Chou and Muller [12]) whereas Montilla et al. [49] (1970) suggested the use of animal or vegetable fat and sugar cane mollases to eliminate the powdery characteristic nature of the diets.

In general conclusions, decreases in weight gains which occurred in both starter and finisher diets but which were significant only in the starter diets at cassava levels higher than 25 percent can be attributed only to the powdery nature of the diets.

From the graph above, it can be observed that the decrease in weight gain is more rapid when cassava substitutes for maize than the decrease in weight gain when cassava substitutes for guinea-corn. This may be due to the fact that the nutrients in guinea-corn are in a form which is more available to the birds or the fact that the amino-acid balance of guinea-corn is better than that of maize.

However, these decreases in weight gains are important only in the economic analysis which follows.

CHAPTER SIX

AN EVALUATION OF THE TECHNICAL AND ECONOMIC PERFORMANCES OF VARIOUS NUTRIENTS AND INGREDIENTS IN BROILER DIETS

Regression analysis has been performed to explore the nutrient content of the diets with known composition to see how the principal nutrient components influenced liveweight gain.

Since typical poultry diets contain numerous feed ingredients, a way had to be found to handle large number of ingredients economically in terms of conducting experimental research. Trials therefore based their response surface estimation on basic nutrients of the feedstuff especially protein and some amino-acids. Experimental results shown in appendix C were used for the regression. Figures show total weight gain and feed intake for the rearing period (6 weeks each for the starters and finishers). Protein, energy and amino-acids intakes were obtained from the feed intake figures. The amounts of nutrients in one kilogram of feed are known. These values are multiplied by the feed intake figures to arrive at nutrient intake. Emphasis is laid on the rate of substitution between the energy-based ingredients - cassava maize and guinea-corn. Analysis was carried out for both single nutrient and nutrient combination effects.

In the following analyses, it is assumed that both genetic and environmental factors that could cause variations in the growth response of the birds are held constant. The adoption of good management practices also insures that only nutritional factors account for variations in the growth response of the birds.

The major causes of variations in the growth rate of the experimental birds are:

(a) The Protein and Energy levels.

(b) The level of Amino-acids

(c) The nutrient sources which determine nutrient availability.

The unexplained variations in weight gains would be due to differences in nutrient availability which result from different nutrient sources in the various diets.

6.1 Single Nutrient Effect

The most important nutrients affecting weight gains have been grouped into

(a) Protein

(b) Energy

(c) Amino-acids:
(i) Lysine
(ii) Methionine + Cystine

6.1.1: Effect of Protein intake on liveweight gain

Protein in the various diets is supplied from different ingredients which make up the composition of the diets. Fortunately, the diets have the same ingredient base making it possible that nutrient sources are the same.

(a) Estimating Procedures

It was stated earlier in chapter four that weight gain depends mainly on feed intake. The mathematical expression is stated as

$$W = f(X, \ldots, V) \qquad \text{(eq. 6.1)}$$

where W = Liveweight gain

X = Feed Intake

V = Error term.

Since protein is supplied by the ingredients in the feed, therefore, weight gain depends also on protein intake. The functional form is stated as

$$W = f(P, \ldots, V) \qquad \text{(eq. 6.2)}$$

where P = Protein intake, and the other terms are as defined earlier.

Two functional equations estimated are stated in the implicit form as

Quadratic $W = b_0 + b_1P + b_2P^2 + V$ (eq. 6.3)

Square Root $W = b_0 + b_1P + b_2P^{\frac{1}{2}} + V$ (eq. 6.4)

From the data obtained from the experiments described in chapter five (See Appendix C) the regression parameters were estimated for the starters and finishers. The method of first difference was applied to cumulative weekly figures in order to eliminate autoregressive disturbances. The figures used therefore revert to the weekly values. The protein coefficient is expected to be positive since intake of more protein is expected to result in increased weight gains. The empirical results follow.

(b) Empirical Results

The quadratic functions have been selected as the lead equations for the following reasons:-

(i) The estimating equation does not seriously contradict theoretical and a priori expectations as to the signs of the regression coefficients.

(ii) Many of the regression coefficients are significant.

(iii) The coefficient of multiple determination (R^2) is such that the function provides a good fit to the data as measured by F-test and,

(iv) The residuals are not serially correlated as tested by the Durbin-Watson test statistics.

The results are presented in Table 5.1.

In all instances, the protein coefficients had the expected positive signs and were significant at the one percent level of probability except in the starters and finishers where guinea-corn was replaced by cassava (experiments III and V). This implies that protein intake is a significant explanatory variable as far as liveweight gain in birds is concerned. Protein in the starters explained 54 percent and in the finishers 30 percent of the total variations in liveweight gain. These low values of R^2 could be due to the fact that protein is not the only

TABLE 6.1: Effects of protein intake on liveweight gain

Equation No.	Experiment	Dependent Variable	Constant Term	Independent Variables: P	Independent Variables: P^2	R^2	F	D.W.	$\alpha = 0.05$: dL	$\alpha = 0.05$: dU
6.5	III	W	626.5	(a)	0.00044 (0.00089)	0.094	0.25	1.83	1.33	1.48
6.6	IV	W	-1026.5	12.62 (4.73)+	-0.02 (0.0076)+	0.53	14.56+	1.10	"	"
6.7	V	W	-3453.0	7.59 (5.95)	-0.00317 (0.0026)	[illegible]	1.03	2.23	"	"
6.8	VI	W	-5189.77	14.29 (7.91)+	-0.0085 (0.0051)++	0.30	6.90+	1.62	1.41	1.52

Experiment III - Starter diets in which cassava replaced guinea-corn
" IV " " " " " Maize
" V Finisher " " " " guinea-corn
VI " " " " " maize

Figures in parentheses are standard errors.
dL - Lower table value of Durbin-Watson
dU - Upper table value of Durbin-Watson
\+ Denotes significance at $P < 0.01$
++ Denotes significance at $P < 0.05$

R^2 is the coefficient of multiple determination
D.W. is the Durbin Watson calculated value
F is the F-test statistic.
(a) Ommission of regression term is due to F or tolerance level being insufficient for further computation.

source of liveweight gain and in addition, it could be that not all the protein taken was available for the birds' metabolism. The Durbin-Watson tests show absence of autocorrelation except in equation 6.6.

6.1.2: Effect of Energy intake on liveweight gain

Energy in the diets is supplied also by the different ingredients which make up the feed. Energy values used were therefore obtained by using the proportion of energy per kilogram of feed and the total feed consumed by the birds. Average weekly figures were regressed on average weekly liveweight gains. (See Appendix C)

(a) Estimating Procedures

It has been stated earlier in section 6.1.1 (a) that weight gain is a function of feed intake

$$W = f(X / \ldots\ldots, V)$$

But $X = f(P, E, A, W)$ (eq. 6.9

where E = Energy

X = Feed intake

A = Amino Acids

Other variables are as previously defined.

$$\therefore W = f(E, / V) \quad \text{(eq. 6.10)}$$

Two functional forms of equation 6.10 are estimated. These are quadratic and square root and their implicit forms are expressed as follows:-

Quadratic $W = b_0 + b_1E + b_2E^2 + V$ (eq. 6.11)

Square root $W = b_0 + b_1E + b_2E^{\frac{1}{2}} + V$ (eq. 6.12

The regression parameters are also estimated for the starters and finishers separately. The energy coefficient is expected to be positive as liveweight gain should increase with increasing energy intake. The empirical results are as shown below.

(b) Empirical Results

The quadratic functions have been selected for the reasons stated earlier in section 6.1.1 (a). The results are presented in Table 6.2 It is only in the case of starter diets in which cassava replaced guinea-corn that the regression parameter is not statistically significant. The coefficients bear the expected positive signs. These show that energy intake contributes significantly to the variations in liveweight gain of the birds. This is confirmed by the F-tests which are significant at the one percent level except for starter and finisher diets in which cassava replaced guinea-corn (experiments III and V). However, energy explained 64 percent in the starters whereas it explained 44 percent in the finishers of the total variations in liveweight gains. These values although higher than those for protein are low. This could be because energy is not the only source of liveweight gain or probably that some of the energy intake was not available for the birds' metabolism. The Durbin-Watson tests show absence of autocorrelation except in equation 6.6.

6.1.3: Effect of Amino-acids on Liveweight Gain

Two vital sets of amino-acids have been found to be most crucial to the health and growth of birds. These are (i) Lysine and (ii) methionine + cystine. More importantly they have been found to be the

TABLE 6.2: Effects of energy intake on liveweight gain

Equation No.	Experiment	Dependent Variable	Constant Term	Independent Variable: E	Independent Variable: E^2	R^2	F	D.W.	$\alpha = 0.05$: dL	$\alpha = 0.05$: dU
6.13	III	W	618.15	0.00001 (0.00001)	(a)	0.011	0.29	1.83	1.33	1.48
6.14	IV	W	-1827.20	1.04 (0.39)+	-0.00012 (0.00005)+	0.54	14.55+	1.10	"	"
6.15	V	W	-9204.67	1.38 (0.73)+	-0.00004 (0.00002)++	0.12	1.71	2.11	"	"
6.16	VI	W	-4340.97	0.92 (0.47)+	-0.00004 (0.00002)++	0.24	5.13+	1.60	1.41	1.52

Experiment III – Starter diets in which cassava replaced guinea-corn
IV – Starter diets in which cassava replaced maize
V – Finisher diets in which cassava replaced guinea-corn
VI – Finisher diets in which cassava replaced maize

Figures in parentheses are standard errors
dL – Lower table value of Durbin-Watson
dU – Upper table value of Durbin-Watson
+ Denotes significance at $P < 0.01$
++ Denotes significance at $P < 0.05$
R^2 is the coefficient of multiple determination
D.W. is the Durbin-Watson calculated value
F is the F-test statistic
(a) Ommission of regression term is due to F or tolerance level being insufficient for further computation.

amino-acids most likely to be limiting in poultry feedstuffs (Fetuga, et al[21] 1975). It is the reason why it had been necessary to supplement them with synthetic sources in the feed.

(i) Lysine

Lysine intake values were calculated from the average feed intake values (See Appendix C).

(a) Estimating Procedures

The relationship between liveweight gain and amino-acids intake had been established in the last section.

$$W = f(X, / \ldots V)$$

$$X = f(P, E, A, V)$$

where $A = f(L, MC, V)$.

A is composed mainly of lysine and methionine + cystine.

$$\therefore \quad W = f(L, V) \qquad \text{(eq. 6.17)}$$

where MC = Methionine plus cystine intake

L = Lysine. Other symbols are as previously defined.

Two functional forms of equation 6.17 are estimated for the starters and finishers separately. The lysine coefficient is expected to be positive as liveweight gain should increase with increasing lysine intake.

(b) Empirical Results

The empirical results are presented in Table 6.3. The quadratic forms are the lead equations.

TABLE 6.3: Effects of lysine intake on liveweight gain

Equation No.	Experiment	Dependent Variable	Constant term	Independent Variable L	L^2	R^2	F	D.W.	$\alpha = 0.05$ dL	dU
6.18	III	W	-152.24	653.83 (420.07)	-120.78 (495.73)	0.013	0.17	1.83	1.33	1.48
6.19	IV	W	-1413.3[illegible]	1397.91 (691.9)$^{+}$	-457.8 (198.7)$^{++}$	0.54	14.6	1.21	"	"
6.20	V	W	-[illegible]294.[illegible]	[illegible]39.86 ([illegible]514.23)$^{++}$	[illegible]197.16 ([illegible])$^{++}$	0.11	1.54	2.13	"	"
6.21	VI	W	-4333.35	1[illegible]71.51 ([illegible]3.22)$^{+}$	-1[illegible]9.59 ([illegible]5.04)$^{++}$	0.23	5.03^{++}	1.58	1.41	1.52

Experiment III - Starter diets in which cassava replaced guinea-corn
" IV - Starter diets in which cassava replaced maize
" V - Finisher diets in which cassava replaced guinea-corn
" VI - Finisher diets in which cassava replaced maize

Figures in parentheses are standard errors
dL - Lower table value of Durbin-Watson
dU - Upper table value of Durbin-Watson
+ Denotes significance at $P \leq 0.01$
++ Denotes significance at $P \leq 0.05$
R^2 is the coefficient of multiple determination
D.W. is the Durbin-Watson calculated value
F is the F-test statistic
(a) Ommission of regression term is due to F or tolerance level being insufficient for further computation.

In all cases, the lysine coefficients had the expected positive signs and were statistically significant except for the starter diets in which cassava replaced guinea-corn (experiment III). This coupled with the significance of the F-tests at the one and five percent levels of probability shows that lysine intake contributes significantly to the variations in liveweight gain in the birds. The low values of R^2 (54 percent in the starters and 11 percent in the finishers) are due to the fact that lysine intake is just one of the factors contributing to liveweight gain. Moreover, the lysine levels in all the diets were above the birds requirements and intake had to be very drastically reduced for the lysine needs to be met. The Durbin-Watson tests show absence of autocorrelation except in the case of starter diets in which cassava replaced maize (equation 6.19).

(ii) Methionine plus Cystine

Methionine and cystine have always been grouped together in specifications of animal feeds. The main reason being connected to their metabolism in the animals. Cystine can always make up for the defficiency of methionine in the diets. Methionine and cystine intake values were calculated also from the average feed intake values (See Appendix C).

(a) Estimating Procedures

The model can be specified as

$$W = f(MC, / \ldots\ldots\ldots, V) \qquad \text{(eq. 6.22)}$$

Two functional forms of equation 6.22 are estimated for the starters and finishers. The functions are

Quardratic $W = b_o + b_1MC + b_2MC^2 + V$ (eq. 6.23)

Square root $W = b_o + b_1MC + b_2MC^{\frac{1}{2}} + V$ (eq. 6.24)

The MC coefficient is expected to be positive.

(b) Empirical Results

The results are presented in Table 6.4. The quadratic functions give the lead equations. The Durbin-Watson test statistic is undeterministic for equation 6.28 and shows autocorrelation in equation 6.26. Non-autoregression occurs in 6.25 and 6.27.

In experiment III, the regression coefficient for methionine plus cystine is not significant. In the finisher diets of experiments V and VI, very low proportions of 12 and 24 percent respectively of the variabilities in liveweight gain are explained by the amino-acids methionine and cystine. In all cases, the lysine coefficient had the expected positive signs. The significance of the F-tests at the one and five percent levels of probability (except in experiment III) shows that cystine and methionine intake contribute significantly to the variations in liveweight gain in the birds. The low levels of R^2 are due to the fact that methionine and cystine are just a part of the factors contributing to liveweight gain. Again they occurred at more than adequate levels and in all diets. The low relationship may also be an indirect indication that HCN toxicity is not very much of a problem because if it were, at increasing levels of cassava inclusion, greater quantities of methionine plus cystine would be called into play in effecting

TABLE 6.4: Effects of methionine and cystine intake on liveweight gain

Equation No.	Experiment	Dependent Variable	Constant term	Independent Variable MC	Independent Variable MC^2	R^2	F	D.W.	$\alpha = 0.05$ dL	$\alpha = 0.05$ dU
6.25	III	W	--538.57	1632.4 (5138.7)	-561.04 (2112.8)	0.004	0.05	1.82	1.35	1.48
6.26	IV	W	-1517.9	3353.3 (1359.3)+	-1369.6 (674.4)++	0.53	13.95+	1.10	"	"
6.27	V	W	-7654.75	4041.10 (2199)++	-473.54 (259.88)++	0.12	1.75	2.15	"	"
6.28	VI	W	-1946.96	1598.26 (538.53)+	- 228.32 (81.81)+	0.24	5.25+	1.44	1.41	1.52

Experiment III - Starter diets in which cassava replaced guinea-corn
" IV - Starter diets in which cassava replaced maize
" V - Finisher diets in which cassava replaced guinea-corn
" VI - Finisher diets in which cassava replaced maize

Figures in parentheses are standard errors
dL - Lower table value of Durbin-Watson
dU - Upper table value of Durbin-Watson
+ Denotes significance at $P < 0.01$
++ Denotes significance at $P < 0.05$

R^2 is the coefficient of multiple determination
D.W. is the Durbin-Watson calculated value
F is the F-test statistic
(a) Ommission of regression term is due to F or tolerance level being insufficient for further computation.

detoxification and thus would be reflected in the growth and therefore utilization of methione and cystine for growth.

6.1.4: Marginal Analysis

Marginal analysis is a way of describing the decision-taking activities of a firm on a simplified and approximate basis. It applies to factors which are available without limit to the firm at given market prices.

Its main advantage is that it offers a variety of general results of the actions of a firm when everything is capable of variation. The technology of the firm is summed up in a single relation of continuously variable form which is the production function. There are no restrictions on the nature of the function and there is no other precise specification. The disadvantage of marginal analysis is that the decisions taken are essentially in the short-run. In marginal analysis only infinitesimal changes in inputs and outputs are considered. These are considered in obtaining the marginal physical productivities and elasticities of production of certain nutrients discussed below.

(a) Protein in Starter Diets

For the broiler starter the production function is as expressed in equation 6.6 which is stated as:-

$$W = -1028.5 + 12.62\,P - 0.02P^2 \qquad \text{(ref. eq. 6.6)}$$

(i) Marginal productivity: is obtained by taking the first differential which gives

$$\frac{dW}{dP} = 12.62 - 0.04P \qquad \text{(eq. 6.29)}$$

At the point of maximum production, MP = 0

$\therefore$ If $\frac{dW}{dP} = 0$,

Then

$$P = \frac{12.62}{0.04} = 315.5 \text{ grams of protein.}$$

(ii) The maximum output contributed by protein is obtained by substituting the value of P into equation 6.6 stated above.

$$W = -1828.5 + 3981.61 - 1990.81$$

$$= 162.3 \text{ grams of liveweight gain.}$$

(iii) The elasticity of production = Ep.

This is defined as the change in output brought about by one percent change in the input. This can be expressed as

$$E_p = \frac{dW}{dP} \times \frac{P}{W} = \frac{MP \times P}{W} \qquad \text{(eq. 6.30)}$$

At the mean value of input $P = \bar{P} = 157.8$ mgs.

$$E_p = \frac{12.62\bar{P} - 0.04\bar{P}^2}{-1828.5 + 12.62\bar{P} - 0.02\bar{P}^2} = 2.97 > 1$$

The elasticity reveals increasing returns to scale as far as protein is concerned and much more so that it is in the starter period. The fact that it is greater than one also indicates that the intake of one unit of protein results in a more than proportionate increase in the weight gain of the bird. This occurs at the mean value of input, however. As more inputs are used, decreasing returns could set in.

(b) Protein in Finisher Diets

For the broiler finisher, the production function is as expressed in equation 6.8 which is stated as

$$W = -5169.77 + 14.29P - 0.0085P^2 \qquad \text{(ref. eq. 6.8)}$$

(i) Marginal Physical Product: Taking the first differential gives

$$MP = \frac{dW}{dP} = 14.29 - 0.017P \qquad \text{(eq. 6.31)}$$

At the maximum weight gain, MP = 0.

$\therefore$ If $\frac{dW}{dP} = 0$,

Then $P = \frac{14.29}{0.017} = 840.58$ grams = 0.841 kgs.

(ii) Maximum Output: The maximum output contributed by protein is obtained by substituting the value of P into equation 6.8 stated above.

$$W = -5169.77 + 12011.88 - 6005.88$$

$$= 836.23 \text{ grams}$$

$$= 0.836 \text{ kgs.}$$

This is the maximum contribution of protein to the total weight gain.

(iii) The elasticity of Production = E_p

As defined for the starters it can be expressed as

$$E_P = \frac{14.29\ \bar{P} - 0.017\bar{P}^2}{-5169.77 + 14.29\bar{P} - 0.0085\bar{P}^2}$$

$$= 3.59 \gg 1$$

The elasticity of production also shows increasing returns to scale in the use of protein during the finishing period. It is pertinent to note that this elasticity is derived at the mean value of input. There could be a point when decreasing returns will set in. The intake of a percentage increase in protein results in a more than proportionate increase in the weight gain of the bird. The proportionate increase in the weight gain of the bird is however greater in the starter than in the finisher.

At greater values of protein intake, say 1600 mgs, decreasing returns will set in. This is shown as follows:

At $\bar{P}$ = 800 mgs,

$$E_P = \frac{11432 - 10880}{-5169.77 + 11432 - 5440} = \frac{552}{822.23}$$

$$= 0.67 \ll 1$$

(c) Energy in Broiler Starter Diets

The production function is as expressed in equation 6.14 which is stated as

$$W = -1827.20 + 1.04E - 0.00012E^2 \qquad \text{(ref. eq. 6.14)}$$

(i) Marginal Physical Product (MP): Taking the first differential of equation 6.14 gives

$$MP = \frac{DW}{dE} = 1.04 - 0.00024E \qquad \text{(eq. 6.32)}$$

At the maximum weight gain

$$MP = 0, \therefore \text{ If } \frac{dW}{dE} = 0,$$

$$\text{Then, } E = \frac{1.04}{0.00024} = 4333.33 \text{ kcals/kg.}$$

(ii) Maximum Weight Gain contributed by energy is obtained by substituting the value of E obtained above into equation 6.14.

$$W = 1827.20 + 4506.67 - 2253.33$$

$$= 426.14 \text{ grams} = 0.426 \text{ kgs. of liveweight gain}$$

(iii) The Elasticity of Production (Ep): As defined earlier, it can be expressed as

$$Ep = \frac{1.04\bar{E} - 0.00024\bar{E}^2}{-1827.2 + 1.04\bar{E} - 0.00012\bar{E}}$$

where $\bar{E}$ is the mean value of energy input

$$\bar{E} = 2166.67 \text{ kcals/kg.}$$

$$Ep = 8.21 > 1.$$

This elasticity of production reveals increasing returns to scale for energy intake too during the starting period. Since the elasticity is greater than one, the intake of one unit of energy results in a more than proportionate increase in the weight gain of the bird. This also is the situation at the mean value of the input.

(d) Energy in Finisher Diets

For the broiler finisher, the production function is as expressed in equation 6.16 which is stated as

$$W = -4340.97 + 3.92E - 0.00004E^2 \qquad \text{(ref. eq. 6.16)}$$

(i) Marginal Physical Product: The **first** differential of equation 6.16 gives

6.2 Nutrient Combination Effects

6.2.1: Effect of Energy and Protein on Liveweight Gain

In the previous section it was established that energy and protein individually, explain only a small part of the variations in liveweight gain. It has therefore become necessary to highlight the effects of the two groups of nutrients on liveweight gain. Most of the ingredients making up the livestock feed have also been grouped into these major nutrients sources.

(a) Estimating Procedures

Liveweight gain can therefore be said to depend on these two major groups of nutrients. This can be expressed as follows:

$$W = f(E, P, /\ldots\ldots, V) \qquad \text{(eq. 6.34)}$$

where

W = Liveweight gain

E = Energy intake

P = Protein intake

V = Error term.

The two functional equations estimated are stated in the implicit form as

Quadratic $W = b_0 + b_1E + b_2P + b_3EP + b_4E^2 + b_5P^2 + V$ (eq. 6.35)

Square root $W = b_0 + b_1E + b_2P + b_3E^{\frac{1}{2}}P^{\frac{1}{2}} + b_4E^{\frac{1}{2}} + b_5P^{\frac{1}{2}} + V$ (eq. 6.36)

Using the calculated data in Appendix C, energy and protein intake values were regressed on liveweight gain. The energy and protein coefficients are expected to be positive since more of their intakes should result in increased weight gains. The empirical results follow.

(b) Empirical Results

The quadratic functions have been selected as the lead equations for reasons stated earlier. The results are presented in Table 6.5.

In all instances, the energy and protein terms which are included in the equations bear the expected positive signs. The regression parameters and F-tests are significant ($P < 0.01$) for experiments IV and V. They explained 3, 54, 22 and 31 percents (R^2) of the variabilities in liveweight gain in experiments III, IV, V and VI respectively. These imply that protein and energy intakes are significant explanatory variables in the liveweight gain of birds. The low values however may be due to the fact that protein and energy are not the only sources of liveweight gain. Also, not all intakes are available for the birds' metabolism. Another factor may be due to the fact that intake levels were used rather than the percentage levels in the diets which have been proved to be a more accurate causal variable by Flinn, et al.[19] in their survey of literature. They claim that from a nutritional view point, the protein level of the diet is a potentially more accurate causal variable than protein intake. It was not possible to use protein level as an explanatory variable in this analysis because the studies were conducted with isoproteinaceous or isonitrogeneous diets. The R^2 values for these combined effects of protein and energy did not differ from the values for their individual effects. This may be because protein

TABLE 6.5 : COMBINED EFFECT OF PROTEIN AND ENERGY ON LIVEWEIGHT GAIN

Equation Number	Experiment	Dependent Variable	Constant term	Independent Variables					R^2	F	D.W.	$\alpha = 0.05$	
				P	E	P^2	E^2	PE				dL	dU
6.37	III	W	607.7	(a)	(a)	-0.012 (0.016)	0.00009 (0.0001)	(a)	0.033	0.42	1.81	1.26	1.56
6.38	IV	W	-1836.5	12.67 (4.73)+	(a)	(a)	-0.00012 (0.00005)+	(a)	0.54	14.6+	1.10	"	"
6.39	V	W	-6606.6	9.1 (3.96)+	0.36 (0.27)	(a)	(a)	-0.00047 (0.00024)+	0.22	2.3	2.33	"	"
6.40	VI	W	-4456.88	12.45 (8.23)	(a)	-0.0063 (0.0057)	(a)	-0.00008 (0.00009)	0.31	4.06+	1.59	1.35	1.59

Experiment III – Starter diets in which cassava replaced guinea-corn
" IV – Starter diets in which cassava replaced maize
" V – Finisher diets in which cassava replaced guinea-corn
" VI – Finisher diets in which cassava replaced maize
Figures in parentheses are standard errors
dL – Lower table value of Durbin-Watson
dU – Upper table value of Durbin-Watson
\+ Denotes significance at $P < 0.01$
++ Denotes significance at $P < 0.05$
R^2 is the coefficient of multiple determination
D.W. is the Durbin-Watson calculated value
F is the F-test statistic
(a) Ommission of regression term is due to F or telorance level being insufficient for further computation.

contributes to the energy. The Durbin-Watson statistic tests show absence of autocorrelation except in equation 6.38.

6.2.2: Effect of Lysine, Methionine and Cystine on Liveweight Gain

The joint effect of the most important amino-acids is considered in this section. This enables the determination of the rates of substitution as well as the elasticity of substitution.

(a) Estimating Procedures

Liveweight gain can be said to be dependent also on the amino-acids intakes of the birds. This is expressed as follows:

$$W = f(L,\ MC,/\ \ldots\ldots,\ V)$$

where

L = Lysine intake

MC = Methionine and Cystine intake

Other terms are as previously defined. The two functional equations estimated are stated in the implicit form as

Quadratic $W = b_o + b_1L + b_2MC + b_3LMC + b_4L^2 + b_5MC^2 + V$ (eq. 6.41)

Square root $W = b_o + b_1L + b_2MC + b_3L^{\frac{1}{2}}MC^{\frac{1}{2}} + b_4L^{\frac{1}{2}} + b_5MC^{\frac{1}{2}} + V$ (eq. 6.42)

Using the calculated data in Appendix C, lysine and methionine plus cystine intake values were regressed on liveweight gain. The lysine and methionine plus cystine coefficients are expected to be positive since more of their intakes should result in increased weight gains. The empirical results are as stated below:-

(b) Empirical Results

The quadratic functions have been selected as the lead equations. The results were as follows: (Table 6.6)

In all instances except in experiment V, the lysine and methionine plus cystine terms which are included in the equations show the expected positive signs. The Durbin-Watson tests show non-autoregression except in equation 6.44. Responsible for the ommission of some terms and low R^2 values is possibly the fact that intake levels were used rather than the percentage levels in the diets. As discussed in Flinn et al [19], Lysine level may be a more accurate causal variable than lysine intake. It is not possible to regress lysine level on liveweight gain because it was constant throughout the diets. If these constant levels are regressed on liveweight gain, multicollinearity would be introduced into the model. There was little or no variation in the methionine and cystine levels in the diets too. The regression parameters are significant except for experiment III. In experiment III, only 3 percent of the variabilities in liveweight gain is explained. They explained 56, 15, 30 in experiments IV, V and VI respectively. This implies that the amino-acids contribute significantly to liveweight in the birds but that they are not the sole sources of liveweight gain. Also, it is not all the intakes that are available for the birds' metabolism.

6.2.3: Marginal Analysis

The marginal analysis concept has been discussed earlier in section 6.1.4 above.

TABLE 6.6: COMBINED EFFECT OF LYSINE AND METHIONINE PLUS CYSTINE ON LIVEWEIGHT GAIN

Equation Number	Experi- ment	Dependent Variable	Constant term	Independent Variables L	MC	L^2	MC^2	LMC	R^2	F	D.W.	$\alpha = 0.05$ dL	dU
6.43	III	W	-735.6	1198.1 (2614.7)	(a)	-203.1 (521.4)	-102.2 (166.4)	(a)	0.03	0.24	1.81	1.26	1.56
6.44	IV	W	-1705.5	(a)	3777.8 (1373)+	(a)	-1971.3 (797.7)+	224.3 (165.2)	0.56	10.2+	1.20	"	"
6.45	V	W	-6147.96	-278.78 (318.5)	4311.19 (2373.89)+	(a)	-515.21 (265.52)+	(a)	0.15	1.46	2.27	"	"
6.46	VI	W	-3280.36	1511.73 (1093.73)	(a)	-429.79 (172.86)+	-430.11 (264.63)	74.40 (448.84)	0.30	3.37	1.76	1.35	1.51

Experiment III - Starter diets in which cassava replaced guinea-corn
" IV - Starter diets in which cassava replaced maize
" V - Finisher diets in which cassava replaced guinea-corn
VI - Finisher diets in which cassava replaced maize
Figures in parentheses are standard errors
dL - Lower table value of Durbin-Watson
dU - Upper table value of Durbin-Watson
+ Denotes significance at $P < 0.01$
++ Denotes significance at $P < 0.05$
R^2 is the coefficient of multiple determination
D.W. is the Durbin-Watson calculated value
F is the F-test statistic
(a) Ommission of regression term is due to F or tolerance level being insufficient for further computation.

In this section, the concept is made use of in determining the marginal rates of substitution between these various nutrients and the elasticity of substitution of one nutrient for another.

(a) Energy and Protein

(i) Marginal Rates of Substitution (MRS): The marginal rate of substitution is defined by the decrease in the use of one nutrient brought about by a unit increase in the use of the other. This concept assumes the fact that maximum liveweight gain can be obtained by the birds with various combinations of protein and energy or the amino-acids. The interest here lies in finding the proportion of one nutrient that will replace one unit of another nutrient.

To obtain the MRS for energy and protein, partial derivatives of the production function of eq.6.39 are determined.

$$W = -6508.6 + 9.10P + 0.36E - 0.00047PE \qquad \text{(ref. 6.39)}$$

The partial derivative with respect to protein gives

$$\frac{dW}{dP} = 9.10 - 0.00047E \qquad \text{(eq. 6.47)}$$

The partial derivative with respect to energy is given as follows:

$$\frac{dW}{dE} = 0.36 - 0.00047P \qquad \text{(eq. 6.48)}$$

To obtain the quantities of energy and protein that will give maximum liveweight gain equations 6.47 and 6.48 are equated to zero. Solving yields

$$E = 19361.702 \text{ kcals/kg.}$$

$$P = 765.96 \text{ grams.}$$

Marginal rate of substitution is obtained at the mean value of these inputs which are

$$\bar{E} = 9880.851 \text{ kcals/kg, and}$$

$$\bar{P} = 382.98 \text{ grams.}$$

MRS is obtained from the ratio of the partial derivates with respect to protein and energy and is given as follows:

$$MRS_{\bar{E}\bar{P}} = \frac{dE}{dP} = -\frac{dW}{dP} \div \frac{dW}{dE} = \frac{-9.19 - 0.00047\bar{E}}{0.36 - 0.00047\bar{P}} \quad \text{(eq. 6.40)}$$

$$= -25.28.$$

This means that a unit increase in energy results in a more than proportionate decrease in protein. The implication is that a high energy diet will result in a low protein diet. Since protein supplying ingredients are cheaper than the energy supplying ones, it will pay a farmer better to use low energy diets and high protein diets. There is however a limit to how low the energy level and how high the protein level could be. This is because a diet with too high calories will reduce feed intake in the birds especially in the hot weather prevailing in this country. If a high caloric diet should be made to have a low protein content then the combined effect would be poor nutrient supply to the birds and this would bring about stunted growth. This would not be of economic advantage to the birds.

(ii) Elasticity of Substitution, (Es): The elasticity of substitution is defined as the percentage increase in the use of one nutrient resulting from a percentage decrease in the use of the other. The knowledge of elasticity throws light on how much of one nutrient can be given up for another nutrient. If much of protein can be given up for a quantity of energy then the farmer can make use of this advantage up to the point at which further substitutions become detrimental to the birds. The elasticity of substitution of energy for protein is expressed as

$$E_s = E_{Ep} = \frac{dE}{dP} \cdot \frac{\bar{P}}{\bar{E}} \qquad \text{(eq. 6.41)}$$

$\bar{P}$ and $\bar{E}$ are the mean values of inputs energy and protein obtained in section (i)a above.

$$E_s = -25.28 \times \frac{382 \cdot 98}{9680 \cdot 85} = -1.0$$

The elasticity of substitution of energy for protein is unitary since it is exactly equal to one. A percentage increase in the energy level results in an equal percentage decrease in the protein level within certain limits.

In making use of the advantages of substituting energy for protein it must be borne in mind that they must be substituted in equal proportions. However, the extent of substitution is limited by the birds' requirements.

(b) Amino-Acids

For the amino-acids the above concepts do not apply because they are essential amino-acids and are required in definite proportions in the birds' metabolism. The question of one substituting for another therefore does not arise.

6.3 Substitution Between Guinea-Corn, Maize and Cassava

In this study, emphasis has been placed on the extent of substitution of cassava for either maize or guinea-corn. This section is to predict gain or growth isoquants indicating the possible combinations of the ingredients which will result in a fixed gain level. Other objectives include predicting their marginal rates of substitution in producing a particular level of gain and predicting isoclines indicating the ingredient combinations for particular gain levels which have the same rate of substitution.

Model

The weight gains obtained in the birds is assumed to be dependent on the energy providing ingredients guinea-corn and maize which cassava is also substituting for in the diets.

6.3.1: Maize and Cassava

(a) Estimating Procedures

The relationship between the ingredients and weight gain is expressed in the implicit form as

$$W = f(M, Ca, /........, V) \qquad \text{(eq. 6.47)}$$

Where W = Liveweight gain

Mz = Maize intake

Ca = Cassava intake

V = Error term.

Two functional equations, the quadratic and square root are estimated. These are expressed as follows:

Quadratic $W = b_0 + b_1M_z + b_2Ca + b_3M^2 + b_4Ca^2 + b_5MCa + V$ (eq.6.48)

Square root $W = b_0 + b_1Mz + b_2Ca + b_3Mz^{\frac{1}{2}} + b_4Ca^{\frac{1}{2}} + b_5mz^{\frac{1}{2}}Ca^{\frac{1}{2}} + V$ (eq.6.49)

Maize and cassava intakes were calculated from their amounts in feed consumed (See Appendix D). These values were regressed on liveweight gain and the parameters estimated using the method of first difference on the cumulative values.

(b) Empirical Results

The quadratic functions have been selected as the lead equations since they satisfied the criteria stated earlier. These are with respect to expected signs of the independent variables, the magnitude of R^2, significance of regression parameters and Durbin-Watson test statistics. The square root functions had lower R^2 values and signs which were contrary to expectations. More terms were excluded also. The results were as follows: (Table 6.7).

TABLE 6.7: COMBINED EFFECTS OF MAIZE AND CASSAVA

Equation Number	Experi- ment	Dependent Variable	Constant term	Independent Variables Mz	Ca	Mz^2	Ca^2	MzCa	R^2	F	D.W.	$\alpha = 0.05$ dL	dU
6.90	Starters	W	-2060.74	5.07	8.07	-0.0023	-0.0055	-0.0071	0.68	9.4+	1.98	1.26	1.56
				(1.01)+	(3.17)+	(0.00094)++	(0.002[illegible])+	(0.0034)+					
6.91	Finishers	W	-1452.37	1.68	[illegible]	-0.00029	-0.00046	-0.00002	0.61	8.29+	2.29	1.31	1.57
				(0.68)+	(0.90)	[illegible]++	(0.00025)++	(0.00037)++					
6.92	Starters and Finishers	W	345.31	0.34	0.18	[illegible]	0.00011	-0.00006	0.70	22.8+	1.70	1.51	1.65
				(0.14)+	(0.18)	(0.0004)	(0.00009)	(0.00009)					

R^2 -- Coefficient of multiple determination

F -- F-statistic

D.W. -- Calculated Durbin-Watson value

dL -- Lower table value of Durbin-Watson statistic

dU -- Upper table value of Durbin-Watson statistic

+ -- Significant at $P < 0.01$

++ -- Significant at $P < 0.05$

Figures in parentheses are standard errors.

The regression coefficients are statistically significant except in the case where the starters and finishers are combined. In all cases, the maize and cassava coefficients had the expected signs, and the significance of the F-tests at the one percent level show that the energy-providing ingredients are significant variables in the model. However, in the starters, the ingredients explained 60 percent and in the finishers, 61 percent. When the whole rearing period is considered, they explained 70 percent. There is evidence that there are other explanatory variables not stated in the model, such as other nutrient supplying ingredients, availability of nutrients, genetic composition of birds and physical conduct of the experiment, etc. There is absence of auto-correlation, therefore the estimates are reliable.

(c) The Response Surface

The production surface was estimated by obtaining all the possible combinations of the two ingredients which will result in a fixed gain level. Equation 6.52 is rearranged in the form $ax^2 + bx + x.$ to conform to equation 6.54.
Equation 6.52 becomes

$$0.00011\,Ca^2 + (3.10 - 0.00006\,Mz)Ca + (0.34Mz - 0.00004Mz^2 + 345.31 - W) \quad \text{(eq. 6.53)}$$

Then,
$$a = 0.00011$$
$$b = (3.16 - 0.00006Mz)$$
$$c = (0.34Mz - 0.00004Mz^2 + 345.31 - W)$$

Solving for Ca gives $Ca = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ (eq. 6.54)

$$Ca = \frac{-(0.18-0.00006Mz) \pm \sqrt{(0.18-0.00006Mz)^2 - 4(0.00011)(0.34Mz-0.00004Mz+3451-W)}}{2(0.00011)} \quad \text{(eq. 6.50)}$$

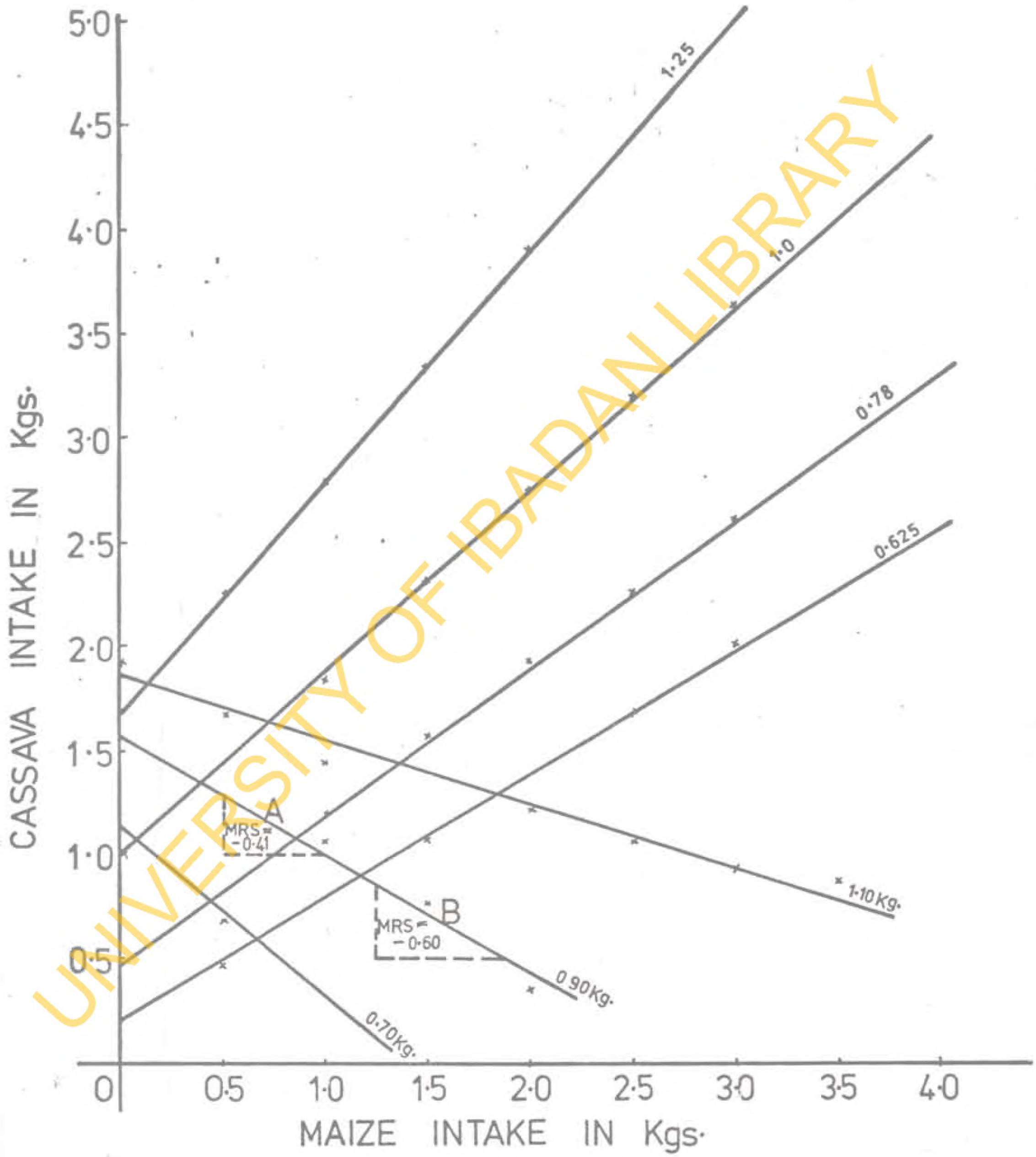
The results for varying levels of maize intake as well as liveweight gain are presented in Table 6.8. The response surface is presented in Figure 6.1. It presents the various isoquants and isoclines for varying gain levels and MRS respectively.

(i) Isoquants: The isoquants shown in Figure 6.1 are not asymptotic to the input (ingredient) axes. This implies that certain output levels can be attained from one input alone when the other is at the zero level. The isoquants are linear and infer that there is no limit to the level of input and output which is profitable[27]. It also indicates that only one of the two ingredients should be used in producing the output.[27] For the output level of 0.9 kilogram gain, the isoquant shows declining marginal rate of substitution as more of cassava and less of maize is included in the food. MRS at point A = 0.41 whereas at point B it is 0.60. This result is significant because looking at the LP outputs of Table 6.4 ~~6.6~~ 6.8, cassava and maize substitute for each other, although cassava is forced in at these levels. If Cassava is not forced in, only maize would have been included in the solution.

TABLE 6.8: MAIZE INTAKE, CASSAVA INTAKE AND AVERAGE WEEKLY LIVEWEIGHT GAIN COORDINATE POINTS ON THE PRODUCTION SURFACE

Maize intake in kgs.	Rate of gain (kgs.) per week			
	0.50	0.70	0.90	1.10
	Cassava intake in Kgs.			
0	0.623	1.155	1.572	1.926
0.5	-0.026	0.58[illegible]	1.239	1.665
1.0		0.34[illegible]	1.071	1.560
1.5		-1.062	[illegible]	1.383
2.0			0.352	1.273
2.5			-0.[illegible]04	1.057
3.0				0.926
3.5				0.855

Fig. 6.1: ISOQUANTS AND ISOCLINES FOR MAIZE AND CASSAVA



(ii) Isoclines: The positively sloped lines in Figure 6.1 are isoclines which connect points of equal slope or equal marginal rates of substitution between the two ingredients. The points on the isoclines are obtained by equating the ratio of marginal productivities to the inverse price ratio[+] The isoclines are linear, positively sloped and are not forced through the origin of the input plane. Since the constant price ratios are greater than zero, the isoclines intersect the cassava axis. Since they do this at quantities greater than zero, they cannot serve as scale lines. As expansion paths, they infer that the proportion of resources must change as higher levels of output or gain are attained if the factor to product price ratio changes[27]. But the change is at a constant rate being a linear line. Table 6.9 shows the points of equal marginal rates of substitution or price ratio.

(d) Marginal Analysis

In this section the concept of marginal analysis is applied to the ingredients as it was applied to the nutrients.

(i) Marginal Physical Products for maize and cassava are derived by obtaining the partial derivates of equation 6.47 with respect to maize and cassava. The production function is expressed as

$$W = 345.31 + 0.34Mz + 0.15Ca - 0.00004Mz^2 + 0.00014Ca^2 - 0.000060CaMz \quad \text{(ref. 6.52)}$$

Partial derivative with respect to maize is given as

$$\frac{dW}{dMz} = 0.34 - 0.00008Mz - 0.000060Ca \quad \text{(eq. 6.56)}$$

[+]Table 6.9

TABLE 6.9: DERIVATION OF POINTS OF THE ISOCLINES ON THE PRODUCTION SURFACE

	Inverse Price Ratios = $\frac{\text{Price of cassava}}{\text{Price of maize}}$			
	$\frac{200}{320} = 0.625$	$\frac{250}{320} = 0.78$	$\frac{250}{250} = 1.00$	$\frac{250}{200} = 1.25$
	Cassava intake in kgs.			
0	0.170	0.492	1.000	1.690
0.5	0.479	0.845	1.430	2.241
1.0	0.781	1.199	2.313	2.793
1.5	1.082	1.652	1.975	3.345
2.0	1.384	1.905	2.750	3.897
2.5	1.628	2.259	3.156	4.448
3.0	1.986	2.612	3.625	5.000

Partial derivative with respect to cassava is given as

$$\frac{dW}{dCa} = 0.18 + 0.00022\,Ca - 0.00006\,Mz \qquad \text{(eq. 6.57)}$$

(ii) Maximum Liveweight Gain is obtained by first finding the quantities of maize and cassava for maximum liveweight gain and then substitituting back in the original production function. These quantities are obtained by setting equations 6.56 and 6.57 equal to zero and solving simultaneously to give cassava = 0.44 kgs.

maize = 2.28 kgs.

These values are then substituted back into equation 6.52.

$$W = 345.31 + 0.34(2280) + 0.18(440) - 0.00034(2280)(2280) + (.00011)(440)(440) - 0.00006(440)(2280)$$

$$= 0.96 \text{ kgs.}$$

This maximum liveweight gain can be compared to the optimum liveweight gain.

(iii) Optimum liveweight gain: The optimum liveweight gain differs from the maximum liveweight gain because it takes the prices of the inputs and outputs into consideration in determining the state at which production should terminate. That is the reason for equating the ratio of marginal physical products to the inverse ratio of input/output prices as stated below. Ratio of equation 6.56 and 6.57 are set equal to inverse ratio of prices as follows.

$$\frac{0.34 - 0.00098\ Mz - 0.00006\ Ca}{0.16 + 0.00022\ Ca - 0.00006\ Mz} = \frac{250/_{2200}}{320/_{2200}} \qquad \text{(eq. 6.58)}$$

Where cost of maize = ₦250/ton

cost of cassava = ₦320/ton

cost of broiler = ₦2200/ton

Equation 6.58 becomes

$$\frac{0.34 - 0.00098\ Mz - 0.00006\ Ca}{0.16 + 0.00022\ Ca - 0.00006\ Mz} = \frac{0.114}{0.145} \qquad \text{(eq. 6.59)}$$

Solving equation 6.59 yields

Maize = 4.931 kgs.

Cassava = 0.2784 kgs.

These values are substituted into equation 6.52 and the optimum live-weight gain obtained is 1057 grams.

= 1.0572 kgs.

This optimal broiler weight is higher than the maximum weight gain. At this optimal weight gain, the bird is between 8-10 weeks old and could serve as roasters. The costs and returns at this stage are discussed in section 6.4. At a higher broiler price or a lower ingredient price the optimal broiler weight changes.

<u>Higher Broiler Price</u>

The optimum liveweight gain at a higher broiler price of ₦3000 per ton is obtained as follows.

$$\frac{0.34 - 0.00008\,Mz - 0.00006\,Ca}{0.18 + 0.00022\,Ca - 0.00006\,Mz} = \frac{250/_{300}}{320/_{3000}} \qquad \text{(eq. 6.60)}$$

Solving equation 6.60 yields

Maize = 3.938 kgs.

Cassava = 0.256 kgs.

Substituting these values into equation 6.52 gives

1056.71 grams = 1.0567 kgs.

This optimum broiler weight at a higher price is lower than the normal optimal broiler weight but the difference is very small being only 0.5 grams.

Lower Ingredient Prices

The optimum liveweight gain is determined at lower ingredient prices. Maize price is reduced from ₦250 to ₦200 per ton and cassava price is reduced from ₦320 to ₦300 per ton.

The ratio of MP equated to the inverse ratio of prices is given as

$$\frac{0.34 - 0.00008\,Mz - 0.00006\,Ca}{0.18 + 0.00022\,Ca - 0.00006\,Mz} = \frac{200/_{2200}}{300/_{2200}} \qquad \text{(eq. 6.61)}$$

Solving equation 6.61 yields

Maize = 4.030 kgs.

Cassava = 0.283 kgs.

Substituting these values into equation 6.52 gives

1056.57 kgs. = 1.0566 kgs.

This optimum broiler weight gain also changes but the change is negligible in this case. (0.60 grams)

(iv) Optimum quantities of ingredients for a given liveweight gain:

To optain the optimum quantities of ingredients for a given liveweight gain, the procedure is as follows:

Equation 6.52 is reduced to the form $ax^2 + bx + c$ and it becomes

$$0.00011Ca^2 - (0.00006Mz + 0.18)Ca + (0.34Mz - 0.00004Mz^2 + 345.31 - W) \quad \text{(eq. 6.62)}$$

For a given liveweight gain of 0.8 kg, we substitute 0.8 kg for W in equation 6.62 above.

$\therefore$ $a = 0.00011$

$b = (-0.00006\ Mz + 0.18)$

$c = (0.34\ Mz - 0.00004\ Mz^2 + 345.31 - 800)$

Solving for cassava using the formula gives

$$Ca = \frac{-(0.00006Mz+0.18) \pm \sqrt{(-0.00006Mz+0.18)^2-4(0.00011)(0.34Mz-0.00004Mz^2-454.69)}}{0.00022} \quad \text{(eq. 6.63)}$$

If maize is 2.40 kgs, then cassava is 0.91 kgs. The value of maize is substituted into equation 6.63 to obtain the quantity of cassava.

(v) Conclusions

It can be observed that the quantities obtained for maximum liveweight gain differ from those for optimum liveweight gain. For maximum liveweight gain:-

maize = 2.28 kgs.

cassava = 0.44 kgs.

For optimum liveweight gain:-

maize = 4.001 kgs.

cassava = 0.276 kgs.

Optimum liveweight gain is higher than the maximum liveweight gain obtained in the experiments. For this higher optimum liveweight gain, more of maize and less of cassava is used than for the lower maximum liveweight gain.

6.3.2: Guinea-Corn and Cassava

(a) Estimating Procedures

For guinea-corn and cassava, the relationship between the ingredients and weight gain is expressed in the implicit form as

$$W = f(GC, Ca, V) \qquad (6.64)$$

where GC = guinea-corn and other symbols and variables are as previously defined. Two functional equations estimated are given as:-

Quardratic $W = b_0 + b_1GC + b_2Ca + b_3GC^2 + b_4Ca^2 + b_5GC\,Ca + V$ (eq. 6. 65)

Square root $W = b_0 + b_1GC + b_2Ca + b_3GC^{\frac{1}{2}} + b_4Ca^{\frac{1}{2}} + b_5GC^{\frac{1}{2}}Ca^{\frac{1}{2}} + V$ (eq.6.66)

Guinea-corn and cassava intakes were calculated from their levels in the feed consumed (See Appendix D). These values were regressed on liveweight gain and the parameters estimated using the method of first difference on the cumulative values.

(b) Empirical Results

The quadratic functions have been selected as the lead equations since they satisfied the aforementioned criteria. The results were shown on Table 6.10. The Durbin-Watson tests show absence of autocorrelation. The regression coefficients are not statistically significant. It is only with either the starters or the finishers that the coefficient for guinea-corn is significant (equation 6.67 and 6.60). The signs are as expected except for equation 6.67 which is for all the starters. For the starters, the square terms show positive signs and there is a positive interaction for guinea-corn and cassava. However, the F-tests are significant at the one percent level of probability showing a joint contribution of the energy providing ingredients to the liveweight gains in the birds. The ingredients explained 83 percent of the variabilities in liveweight gain of the birds in the starters, whilst 66 percent is explained in the finishers and only 59 percent when the starters and finishers are combined. This confirms that there are other explanatory variables in the model.

(c) The Response Surface

The production surface was obtained by estimating all the possible combinations of the two ingredients which will result in a fixed gain level.

TABLE 6.10: COMBINED EFFECTS OF GUINEA-CORN AND CASSAVA ON LIVEWEIGHT GAIN

Equation Number	Experiment	Dependent Variable	Constant term	Independent Variables					R^2	F	D.W.	$\alpha = 0.05$	
				GC	Ca	GC^2	Ca^2	GC Ca				dL	dU
6.67	Starters	W	566.0	0.57 (1.35)	-2.30 (2.12)	0.0075 $(0.00078)^{+}$	0.0032 $(0.0017)^{++}$	0.0033 (0.0024)	0.83	21.95^{+}	2.34	1.22	1.56
6.68	Finishers	W	-1216.40	1.51 $(0.83)^{++}$	1.47 (1.02)	-0.00025 (0.00017)	-0.00028 (0.00027)	-0.00052 (0.0004)	0.68	10.87^{+}	2.26	1.31	1.57
6.69	Starters and Finishers	W	361.02	0.32 $(0.10)^{+}$	0.13 (0.15)	-0.00003 (0.00003)	-0.00002 (0.00009)		0.59	19.94^{+}	1.76	1.51	1.65

R^2 – Coefficient of multiple determination

F – F-Statistic

D.W. – Calculated Durbin-Watson value

dL – Lower table value of Durbin-Watson statistic
dU – Upper table value of Durbin-Watson statistic
+ – Significant at $P < 0.01$
++ – Significant at $P < 0.05$
Figures in parentheses are standard errors.

Equation 6.69 is rearranged in the form of $ax^2 + bx + c$. It becomes

$$-0.00002\, Ca^2 + 0.13\, Ca + (0.32\, GC - 0.00003\, GC^2 + 361.02 - W) \quad \text{(eq. 6.7)}$$

Then,
$$a = -0.00002$$
$$b = 0.13$$
$$c = (0.32\, GC - 0.00003\, GC^2 + 361.02 - W).$$

Solving for cassava with equation 6.54 gives

$$a = \frac{-(0.13) \pm (0.13)^2 - 4(-0.00002)(0.32\, GC - 0.00003\, GC^2 + 361.02 - W)}{2(-0.00002)} \quad \text{(eq. 6.71)}$$

The results for varying guinea-corn intake as well as liveweight gain are presented in Table 6.11. The response surface is presented in Figure 6.2. It presents the various isoquants and isoclines for varying gain levels ranging from 0.50 kg. to 1.10 kg. and MRS ranging from 0.625 to 1.10. The isoquants shown in Figure 6.2 are not asymptotic to the input (ingredient) axes. This signifies that certain output levels can be attained from one input alone when the other is at the zero level. The isoquants are non-linear and are downward sloping. This indicates that the rate of substitution of cassava for guinea-corn declines for a given output with more of cassava and less of guinea-corn.[27] For the output level of 0.90 kg. gain, MRS at A = -2.10 whereas at point B, it is -2.20.

Fig. 6.2: ISOQUANTS AND ISOCLINES FOR GUINEA-CORN AND CASSAVA

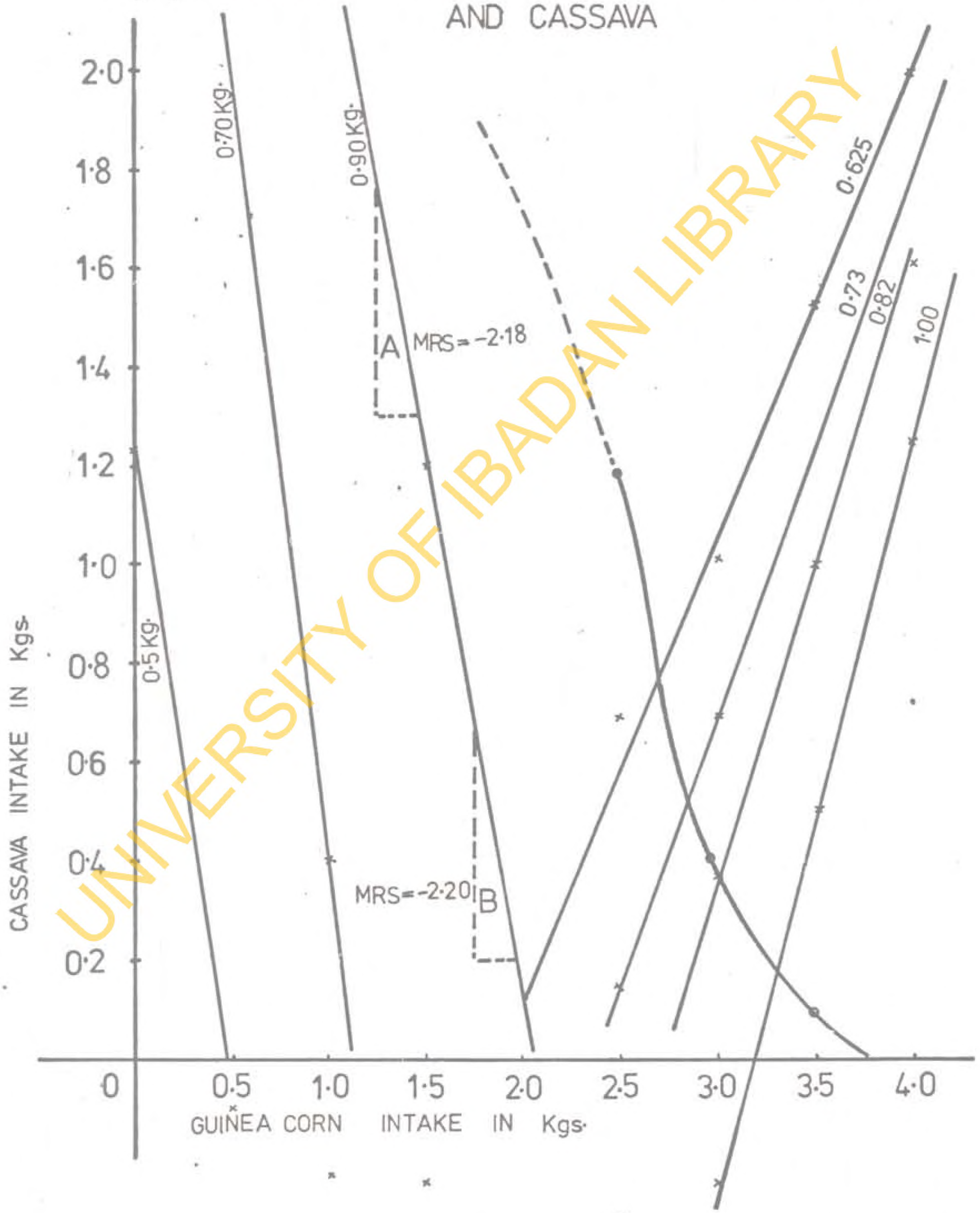


TABLE 6.11: GUINEA-CORN INTAKE, CASSAVA INTAKE AND AVERAGE WEEKLY LIVEWEIGHT GAIN COORDINATE POINTS ON THE PRODUCTION SURFACE

Guinea-corn intake in kgs.	Rate of gain (kgs.) per Week			
	0.50	0.70	0.90	1.10
	Cassava intake in kgs.			
0	1.35	5.777	7.[illegible]	8.337
0.5	-0.10	2.125	6.210	7.582
1.0		0.400	4.625	6.698
1.5		-0.523	1.200	5.350
2.0			0.150	3.872
2.5			-0.523	1.191
3.0				0.400
3.5				0.100

<u>Isoclines</u>

The positively sloped lines in figure 6.2 are the corresponding isoclines for guinea-corn and cassava since they connect points of equal MRS or inverse price ratios of the two ingredients. Table 6.12 shows the points of equal price ratio or marginal rates of substitution. The isoclines are linear, and do not pass through the origin. This indicates that the mix of ingredients should change as output is expanded or product or factor prices change but the rate of change should be constant. The isoclines cannot serve as scale lines because they intersect the maize axis at quantities less than zero (i.e. at negative values)

(c) <u>Marginal Analysis</u>

The concept of marginal analysis is applied also to the case in which cassava substituted for guinea-corn in the case of ingredients as was done for the nutrients.

(i) <u>Marginal Physical Products</u>: From equation 6.69

$$W = 361.02 + 0.32GC + 0.13Ca - 0.00003GC^2 - 0.00002\ Ca^2 \quad \text{(ref. eq.6.69)}$$

$$\frac{dW}{dGC} = 0.32 - 0.00006\ GC \qquad \text{(eq. 6.72)}$$

$$\frac{dW}{dCa} = 0.13 - 0.00004\ Ca \qquad \text{(eq. 6.73)}$$

TABLE 6.12: DERIVATION OF POINTS OF THE ISOCLINES ON THE PRODUCTION SURFACE

	Inverse Price Ratios = Price of cassava / Price of guinea-corn			
	200/320 = .625	320/300 = 0.73	180/220 = 0.82	220/220 = 1.0
	Cassava	intake	in	kgs.
1.5	-0.344			
2.0	0.125	-0.400		
2.5	0.594	0.148	-0.235	
3.0	1.063	0.695	-0.380	-0.250
3.5	1.531	1.243	0.995	0.500
4.0	2.000	1.790	1.510	1.250

Setting equations 6.72 and 6.73 to zero, and solving simultaneously yields

$$GC = 5.33 \text{ kg.}$$

$$Ca = 3.25 \text{ kg.}$$

(ii) Maximum liveweight gain is obtained by substituting the above values into equation 6. 69

Maximum liveweight gain

$$= 361.02 + 1706.56 + 422.5 - 853.23 - 211.25$$

$$= 1425.6 \text{ grams}$$

$$= 1.43 \text{ kg.}$$

This maximum liveweight gain is higher than in the case when maize is used. It also allows a higher ratio of cassava to guinea-corn which is 3:5 whereas for cassava to maize it is 1:5. This higher weight gain may not be justified by the higher cost of cassava which is included in the diet.

(iii) Optimum quantities of cassava and guinea-corn required for a given liveweight gain: First, the optimum quantities of guinea-corn and cassava for optimum liveweight gain are obtained by equating the ratio of marginal products obtained in equations 6. 74 and 6. 75 to the inverse ratio of prices

$$\frac{0.32 - 0.00006\ GC}{0.13 - 0.00004\ Ca} = \frac{220}{320} \qquad \text{(eq. 6.74)}$$

Or

$$0.32 - 0.00006\ GC = \frac{320}{2200} \qquad (6.75)$$

and,

$$0.13 - 0.00004\ Ca = \frac{320}{2200} \qquad (6.76)$$

Solving equations 6.75 and 6.76 simultaneously yields

1.661 kgs of guinea-corn, and

3.633 kgs of cassava.

For a given liveweight gain of 0.80 kg. the optimum quantities of GC and Ca are obtained by substituting W = 800 gms into the form

$$Ca^{*} = \frac{-(0.13) \pm \sqrt{0.0169 - (0.00002)(0.32GC - .0003GC^{2} + 361.02 - 800}}{-0.00004} \quad \text{(eq. 6.97)}$$

When guinea-corn is 1.661 kgs, cassava = 6.58 kgs. Optimum quantities of GC and Ca for 0.8 kg. liveweight gain are 1.661 kgs. and 6.58 kgs. respectively. The quantities for maximum gain are quite different for the quantities for the optimum liveweight gain and these in turn differ from the quantities for a given liveweight gain of 0.80 kg. To obtain the same liveweight gain of 0.80 kg., more of cassava and guinea-corn are required than for maize and cassava.

(iv) Optimum liveweight gain To obtain this, the optimum quantities of cassava and guinea-corn obtained earlier from equations 6.75 and 6.76 are substituted back into equation 6.97 GC = 1661.33, Ca = 3633 grams

$$W = 361.02 + 0.32GC + 0.13Ca - 0.00003\ GC^{2} - 0.00002\ GC^{2}$$

$$W = 361.02 + 531.63 + 472.29 - 82.83 - 263.92$$

$$W = 1018.14 \text{ grams} = 1.018 \text{ kg.}$$

At this optimal broiler weight, the birds are about 8 weeks old and could serve as roasters. The optimum broiler weight gain is lower than the maximum liveweight gain whereas when cassava substitutes for maize, the maximum weight gain is lower than the optimum weight gain. The optimal liveweight gain when cassava and guinea-corn are used are lower than the optimal broiler weight when cassava and maize are used.

6.4 Economic Analysis of the Diets

The aim of any commercial enterprise such as poultry farming is to make maximum possible profit. In an economy where little value is placed on carcass quality of birds, revenue is determined by the total weight attained during the rearing period and the cost and quantity of feed required. Revenue would therefore depend mainly on the rate at which feed gets converted to liveweight gains (growth rate), the quantity of feed required per unit liveweight gain (feed conversion efficiency), the cost of the feed, and the market value of the birds. Therefore, to determine which diet is best or to find the optimum marketing age, the criteria to be used are

(i) The diet providing the fastest growth rate,

(ii) the diet which gives the feed conversion efficiency that maximises net revenue over feed costs,

(iii) value of bird at market weight and finally,

(iv) the net revenue over feed costs.

For a meaningful analysis, the starter and finisher diets have been merged so that the whole rearing period is considered.

6.4.1: The optimum marketing age/weight

To be able to know which age is best for the farmer to sell off birds, revenue over feed costs have been obtained at different ages and marketable weights. Five stages at 6, 8, 10, 11 and 12 weeks were considered in this analysis. The value of the weight gain up to a stage is obtained by the birds weight multiplied by the market value. The quantity of feed taken by the bird up to that stage is multiplied by the unit cost. The difference between the revenue and cost of feed at each stage is thus obtained. Table 6.13 shows revenue over feed costs at each of five stages of growth for diets in which cassava replaced guinea-corn. It can be observed from the C columns that for most of the diets, the maximum profit margin is obtained at eleven weeks of age. It is only in diets GCC1 and 8, GCC2 and 9, GCC3 and 10 that a higher revenue is obtained at the 12 weeks of age. It is therefore best for the farmer to sell off the birds at 11 weeks of age. This shorter rearing period also enables the farmer to have more batches of chicks to raise within a year. This increases the profit of the farmer per year. Table 6.14 shows the revenue over feed costs at the five stages stated earlier for diets in which cassava replaced maize. The maximum revenue over feed costs for the diets is also obtained at the eleven weeks of age. Therefore, for the cassava based diets, the birds yield the highest revenue at an earlier age. It pays the farmer to sell off the birds at eleven weeks when they are just about 1.8 kg. weight. This is the point at which the value of

TABLE 6.13: Revenue over feed costs at 6, 8, 10 and 12 weeks of age for diets in which cassava replaced guinea-corn (₦/bird)

Diets+	6 Weeks			8 Weeks			10 Weeks			11 Weeks			12 Weeks		
	a_1 Value++ of feed	b_1 Value of bird	c_1 Revenue over feed costs	a_2 Value of feed	b_2 Value of bird	c_2 Revenue over feed costs	a_3 Value of feed	b_3 Value of bird	c_3 Revenue over feed costs	a_4 Value of feed	b_4 Value of bird	c_4 Revenue over feed costs	a_5 Value of feed	b_5 Value of feed	c_5 Revenue over feed cost
GCC1&8	0.371	1.483	1.112	0.621	2.215	1.594	0.987	3.089	2.102	1.167	3.406	2.239	1.321	3.771	2.45
GCC2&9	0.364	1.236	0.872	0.604	2.354	1.75	0.968	2.963	1.995	1.173	3.246	2.073	1.367	3.607	2.24
GCC3&10	0.405	1.459	1.054	0.663	2.200	1.54	1.015	3.128	2.113	1.216	3.306	2.090	1.414	3.584	2.17
GCC4&11	0.44	1.291	0.851	0.691	2.094	1.403	1.04	2.908	1.868	1.233	3.096	1.862	1.417	3.177	1.76
GCC5&12	0.45	1.225	0.775	0.729	2.035	1.307	1.021	2.913	1.872	1.241	3.163	1.922	1.529	3.159	1.63
GCC6&13	0.420	1.349	0.901	0.710	2.079	1.369	1.056	2.905	1.849	1.263	3.006	1.743	1.507	3.197	1.69
GCC7&14	0.423	1.065	0.642	0.799	2.026	1.227	1.204	2.985	1.781	1.249	2.976	1.727	1.604	2.664	1.06
Comm. I	0.560	1.463	0.895	0.944	2.369	1.425	1.402	3.390	1.988	1.412	3.495	2.083	1.817	3.507	1.69
Comm. III	0.693	1.654	0.961	1.135	2.523	1.388	1.724	3.980	2.255	1.849	4.149	2.300	2.376	4.206	1.83

+Diets GCC1–7 are starter diets in which cassava replaced guinea-corn

GCC8–14 are finisher diets in which cassava replaced guinea-corn

++Cost of computerised diets were increased by 22.48%[56] to make up for overhead charges which commercial diets included.

TABLE 6.14: Revenue over feed costs at 6, 8, 10 and 12 weeks of age for diets in which cassava replaced maize (N/bird)

Diets+	6 Weeks			8 Weeks			10 Weeks			11 Weeks			12 Weeks		
	a_1 Value of feed	b_1 Value of bird	c_1 Revenue over feed costs	a_2 Value of feed	b_2 Value of bird	c_2 Revenue over feed costs	a_3 Value of feed	b_3 Value of bird	c_3 Revenue over feed costs	a_4 Value of feed	b_3 Value of bird	c_4 Revenue over feed costs	a_5 Value of feed	b_5 Value of bird	c_5 Revenue over feed costs
MC 1 & 8	0.425	1.344	0.919	0.733	2.116	1.383	1.103	2.525	1.422	1.324	3.219	1.895	1.477	3.302	1.83
MC 2 & 9	0.451	1.476	1.025	0.751	[illegible]	1.557	1.117	3.038	1.921	1.35	3.250	1.930	1.591	3.421	1.83
MC 3 & 10	0.432	1.412	0.98	0.728	2.294	1.566	1.112	3.231	2.119	1.137	3.275	2.133	1.548	3.368	1.82
MC 4 & 11	0.441	1.439	0.998	0.751	2.286	1.535	1.141	3.164	2.023	1.152	3.22	2.068	1.584	3.401	1.82
MC 5 & 12	0.429	1.263	0.834	0.726	2.152	1.426	1.120	3.221	2.101	1.152	3.255	2.103	1.525	3.352	1.83
MC 6 & 13	0.464	0.902	0.438	0.753	2.036	1.283	1.167	3.068	1.901	1.093	3.002	1.909	1.437	2.997	1.56
MC 7 & 14	0.432	1.157	0.725	0.701	2.315	1.614	1.123	2.956	1.833	1.158	3.00	1.845	1.304	2.440	1.14
Comm. I	0.560	1.463	0.895	0.944	2.369	1.425	1.402	3.393	1.993	1.412	3.495	2.083	1.817	3.507	1.69
Comm.III	0.693	1.654	0.961	1.135	2.523	1.388	1.724	3.980	2.256	1.849	4.149	2.300	2.376	4.206	1.83

+Diets MC 1 – 7 are starter diets in which cassava replaced maize
MC 8 – 14 are finisher diets in which cassava replaced maize

Cost of computerised diets were increased by 22.48% [53] to make up for overhead charges which the commercial diets included.

weight added is greater than or equal to the value of feed taken. The farmer also has the opportunity of having more batches in a year. In the Nigerian situation however, demand is for heavier/older birds.

6.4.2: Comparison of Net Revenue from diets

The next series of analyses deal with the comparisons of net revenue over the entire rearing period for all the experiments.

(i) Computerised diets with varying fibre and protein levels In the first set of diets shown in table 6.15, six different diets emerge from the various combinations of the starter and finisher diets of experiment II which was discussed earlier in chapter four. There are four diets in which each starter is matched with each of the finisher. The remaining two are commercial diets.

Table 6.15 summarises the net revenue over feed costs for the four different pairs of starters and finishers and the two commercial diets under consideration.

Using the criterion of net revenue over feed costs, it can be seen from the table below that combinations of either starter 7 with finisher 9 or 10 are the best, followed by combinations of starter 2 with either finisher 9 or 10. Commercials I and II follow third and fourth respectively. In general, the computerised diets gave higher net revenue over feed costs.

It is pertinent to note here that lack of statistical significance in technical efficiency parameters of two diets does not necessarily mean that both diets are equally economically good (as reported

TABLE 6.15: Summary of Net Revenue over feed costs per bird for diets in experiment II for the whole of the rearing period

	1 DIETS	2+ Feed costs ₦ N/kg.	3 Feed consumed for 12 weeks kg.	4 Value of feed consumed ₦	5 Weight gained on diets for 12 weeks kg.	6++ Value of Weight gained ₦	6-4 Net Revenue over feed costs ₦
2	Starter	0.26	1.60	0.41	0.59	1.29	2.60
9	Finisher	0.25	3.39	0.92	1.20	2.64	
2	Starter	0.26	1.60	0.41	0.59	1.29	2.50
10	Finisher	0.23	3.69	0.85	1.17	2.57	
7	Starter	0.24	1.86	0.45	0.77	1.69	2.96
9	Finisher	0.25	3.69	0.92	1.20	2.64	
7	Starter	0.24	1.86	0.45	0.77	1.69	2.96
10	Finisher	0.23	3.69	0.85	1.17	2.57	
COMMERCIAL I	Starter	0.33	1.81	0.60	0.64	1.41	2.27
	Finisher	0.30	3.93	1.18	1.20	2.64	
COMMERCIAL III	Starter	0.34	2.28	0.76	0.65	1.43	2.01
	Finisher	0.30	3.88	1.01	1.07	2.35	

+Prices of computerised diets were increased by 22.48% to make up for the overhead charges which the commercial diets included. The figure was the average of overhead costs of four model manufacturing plants given in Ogunfowora, et al. 56/

++Price of ₦2.20/kg. liveweight was used. It is the price used on the University Teaching and Research Farm.

in feeding experiments in chapter V), neither does it hold that a diet statistically significantly superior to another diet in an efficiency yardstick is necessarily better economically. For example, diets 7 and 9 had better feed efficiency indices than diets 2 and 10 yet, their combinations are the same in terms of net revenue over feed costs. That is, combining diet 7 with diets 9 and 10 gave the same profit as when diet 2 is combined with diets 9 and 10. However, diets 9 and 10 yield the same revenue even though their protein contents vary. Diet 9 had 22 percent protein whereas diet 10 had 20 percent protein whilst their fibre levels were the same. Diet 7 performed better than diet 2 even though its protein content of 24 percent is lower than that of diet 2 which had 26 percent. It can be inferred then that a 24 percent protein starter diet is better than a 26 percent protein diet.

(ii) Diets in which cassava replaced guinea-corn The summary of net revenues over feed costs for experiments of starter and finisher diets in which cassava replaced guinea-corn is presented in Table 6.16. Both starter and finisher diets in which guinea-corn replaced cassava at the various levels were considered along with two commercial diets. Diets GCC 8 - GCC 16 had cassava levels of 0, 5, 10, 15, 20, 26, 30, 35 and 40 percent respectively. Finisher diets GCC 15 and GCC 16 are excluded from the analysis since there are no starter diets to match.

It was observed in chapter five that significant differences occurred in the starter diets and the finisher diets. ..

TABLE 6.16: Summary of Net Revenue over feed costs per bird for seven diets in which cassava replaced guinea-corn in the diets and two commercial diets

1 DIETS	2 Cassava level	[illegible]	3[+] Feed costs ₦/kg.	4 Feed consumed kg.	5 Value of feed consumed ₦	6 weight gained on diets kg.	7[++] Value of weight gained ₦	(7-5) Net Revenue over feed costs ₦	
GCC 1 GCC 8	0%	Starter Finisher	0.235 0.21	1.58 4.543	0.371 0.954	0.674 1.04	1.483 2.288	1.112 1.334	2.45
GCC 2 GCC 9	5%	Starter Finisher	0.244 0.22	1.49 4.555	0.364 1.002	0.562 0.805	1.236 1.771	0.872 0.769	2.24
GCC 3 GCC 10	10%	Starter Finisher	0.253 0.224	1.60 4.493	0.405 1.006	0.663 0.966	1.4[illegible] 2.1[illegible]	1.054 1.119	2.17
GCC 4 GCC 11	15%	Starter Finisher	0.262 0.23	1.68 4.237	0.44 0.975	0.587 0.857	1.2[illegible] 1.885	0.851 0.910	1.76
GCC 5 GCC 12	20%	Starter Finisher	0.271 0.234	1.66 4.60	0.45 1.076	0.557 0.879	1.225 1.934	0.775 0.858	1.63
GCC 6 GCC 13	25%	Starter Finisher	0.28 0.24	1.60 4.407	0.448 1.058	0.613 0.840	1.349 1.848	0.901 0.790	1.69
GCC 7 GCC 14	30%	Starter Finisher	0.29 0.246	1.46 4.788	0.423 1.178	0.484 0.727	1.065 1.599	0.642 0.421	1.06
Commercial	I	Starter Finisher	0.33 0.30	1.72 4.179	0.568 1.254	0.665 0.929	1.463 2.044	0.895 0.790	1.69
Commercial	III	Starter Finisher	0.398 0.398	1.74 4.235	0.693 1.686	0.752 1.16	1.654 2.552	0.961 0.866	1.83

[+] Prices of computerised diets were increased by 22.48% to make up for the overhead charges which the commercial diets included. The figure was the average of overhead costs of four model manufacturing plants given in Ogunfowora, et al.[56]

[++] Price of ₦2.20/kg. liveweight was used. It is the price used on the University Teaching and Research Farm Ibadan

In this economic analysis, it can be seen that the net profit varies as the cassava content of the diet varies. There is evidence that revenue decreases as the percentage cassava content of the diet increases.

Diets GCC 2 and 9 (5% cassava) yield the highest revenue of ₦2.24 per bird when comparing diets with cassava. The revenue decreased to ₦1.06 per bird in diets GCC 7 and 14 which contained 30 percent cassava. However, diets containing up to 10 percent cassava had higher or equal revenue with the commercial diets. The reason is that these commercial diets are a lot costlier than the computerised diets and their higher weight gains could not offset the costs. Diets with higher cassava levels are costlier because cassava is costlier than the grains. Profit levels are therefore obtained using different costs of the diets as cassava price varies. Computations are shown in Table 6.17.

(a) Revenue with varying cassava prices

When cassava was made to assume the same price with guinea-corn (₦220 per ton), all the computerised diets had higher net profits than the commercial diets except for diets GCC 2 and 9 and GCC 7 and 14. Diets GCC2 & 9 gave equal net profits with commercial I. At this cassava price and lower prices of ₦170 and ₦120 per ton, diets GCC 7 & 14 gave the lowest revenue. However, revenue obtained when lower cassava prices are used are always higher than for higher prices of cassava. For instance, diets GCC 3 and 10 gave the highest revenue of ₦2.25 per bird

TABLE 6.17: Summary of Net Revenue over feed costs per bird at varying costs of feed (Varying costs of cassava) when cassava is replaced by guinea-corn in the diets

1 DIETS	Cassava levels		3 Cost of feed at+ Varying prices of cassava ₦			4 Feed Consumed kgs.	5 Value of feed consumed at varying cassava prices ₦			6++ Value of Weight gained ₦	7 Net Revenue over feed costs at varying cassava prices (6-4)		
			₦220	₦170	₦120		₦220	₦170	₦120		₦220	₦170	₦120
GCC 1	0%	Starter	0.235	0.235	[illegible]	1.53	1.348	1.348	1.348	3.771	2.423	2.423	2.423
GCC 8		Finisher	0.215	0.215	0.215	4.543							
GCC 2	5%	Starter	0.238	0.235	[illegible]	1.49	1.325	1.307	1.289	3.007	1.682	1.70	1.718
GCC 9		Finisher	0.213	0.210	[illegible]	4.555							
GCC 3	10%	Starter	0.241	0.235	0.229	1.60	1.338	1.302	1.255	3.584	2.246	2.282	1.319
GCC 10		Finisher	0.212	0.206	0.200	4.493							
GCC 4	15%	Starter	0.244	0.235	0.225	1.68	1.304	1.246	1.192	3.176	1.872	1.930	1.984
GCC 11		Finisher	0.211	0.201	0.192	4.237							
GCC 5	20%	Starter	0.247	0.235	0.222	1.66	1.376	1.304	1.220	3.159	1.783	1.852	1.939
GCC 12		Finisher	0.210	0.198	0.185	4.60							
GCC 6	25%	Starter	0.250	0.235	0.219	1.60	1.321	1.231	1.139	3.197	1.876	1.966	2.058
GCC 13		Finisher	0.209	0.194	0.179	4.407							
GCC 7	30%	Starter	0.253	0.235	0.217	1.46	1.370	1.258	1.140	2.664	1,294	1.406	1.524
GCC 14		Finisher	0.209	0.194	0.172	4.788							
Commercial	I	Starter	0.33			1.72	1.822			3.507	1.69		
		Finisher	0.30			4.179							
Commercial	III	Starter	0.396			1.74	2.379			4.206	1.83		
		Finisher	0.398			4.235							

+Prices of computerised diets were increased by 22.48% to make up for the overhead charges which the commercial diets included. The figure was the average of overhead costs of four model manufacturing plants given in Ogunfowora, et al.[66]

++Price of ₦2.20/kg. liveweight was used. It is the price used on the University Teaching and Research Farm, Ibadan at cassava price of ₦220 per ton. For diets GCC 7 and 14 which gave the least net revenue, it gave ₦1.52 per bird when cassava costs ₦120 per ton and ₦1.29 per bird when cassava costs ₦220 per ton.

(iii) Diets in which cassava replaced maize This analysis is with diets in which cassava substituted for maize rather than guinea-corn. The diets were those in which cassava replaced maize in the starters and finishers described earlier in chapter five. The summary of net revenue over feed costs [illegible] for experiments four and six is presented in Table 6.17. Diets MC 8 – MC 16 had cassava levels of 0, 5, 10, 15, 20, 25, 30, 35 and 40 percent respectively. Finisher diets MC 15 and MC 16 are excluded from the analysis because there are no starter diets of equal cassava content to match. The results here are similar to those obtained for guinea-corn in Table 6.16 except for the fact that the net revenue in these diets are lower than those in which cassava replaced guinea-corn rather than maize. This could be due to the fact that guinea-corn based diets are cheaper than the maize based diets because guinea-corn is cheaper than maize. It could also be due to the fact that performance is better with guinea-corn based diets than the maize based diets. For the maize based diets, diets MC 5 and 12 gave the highest revenue of ₦1.84 per bird whilst diets MC 7 and 14 gave the least revenue of ₦1.14 per bird. Here, diets with cassava levels of up to 20 percent had higher or equal revenue with the commercial diets.

It can be seen also that it is the higher cost of the commercial diets relative to the computerised diets that reduced the revenue accruing to the farmer from these commercial diets. This shows that an attempt at a critical assessment of feed production costs may reduce feed prices and thus increase the profit margins of poultry producers, and encourage the expansion of the industry. Of particular importance is the indication that cassava can be used up to a fairly high level without adversely affecting the performance of the birds.

(a) Revenue with varying cassava prices

Since diets containing higher cassava levels are costlier because cassava is costlier than the grains, it becomes necessary to view what happens to net revenue if cassava prices are lowered. Profit levels were therefore obtained using different costs of the diets as cassava price varies. Computations are shown in Table 6.19. When cassava assumes lower prices, the costs of the feed are considerably reduced thus raising the net revenue as shown in Table 6.19. For diets MC 2 and 9 for instance, revenue rises from ₦1.73 per bird when cassava costs ₦320/ton (Table 6.18) to ₦1.81 per bird when cassava costs ₦120 per ton (Table 6.19). However, the revenue when maize is used to replace cassava are much lower than when guinea-corn is used (compare Tables 6.18 and 6.19). The revenue for the computerised diets at lower prices of cassava are higher than the revenues given by the commercial diets except for diets MC 2 & 9 and MC 7 and 14. MC 2 and 9 however give a higher net revenue than

TABLE 6.18: Summary of Net Revenue over feed costs per bird from seven diets in which cassava replaced maize in the diets and two commercial diets

[1] DIETS	Cassava Levels		3 Feed costs[+] ₦/kg.	4 Feed consumed kg.	5 Value of feed consumed ₦	6 Weight gained on diets kg.	7[++] Value of weight gained ₦	(7-5) Net Revenue over feed costs ₦	
MC 1 MC 8	0%	Starter Finisher	0.256 0.237	1.66 4.430	0.425 1.052	0.611 0.89	1.344 1.958	0.919 0.906	1.83
MC 2 MC 9	5%	Starter Finisher	0.259 0.239	1.74 4.766	0.451 1.14	0.671 0.837	1.476 1.841	1.025 0.701	1.73
MC 3 MC 10	10%	Starter Finisher	0.262 0.241	2.65 4.632	0.432 1.116	0.642 0.856	1.412 1.883	0.98 0.767	1.75
MC 4 MC 11	15%	Starter Finisher	0.267 0.244	1.65 4.671	0.441 1.14	0.654 0.892	1.439 1.962	0.998 0.822	1.82
MC 5 MC 12	20%	Starter Finisher	0.275 0.247	1.56 4.586	0.429 1.133	0.574 0.974	1.263 2.143	0.834 1.01	1.84
MC 6 MC 13	25%	Starter Finisher	0.283 0.250	1.64 3.89	0.464 0.973	0.410 0.953	0.902 2.097	0.438 1.123	1.56
MC 7 MC 14	30%	Starter Finisher	0.292 0.253	1.40 3.448	0.432 0.872	0.526 0.583	1.157 1.283	0.725 0.411	1.14
Commercial	I	Starter Finisher	0.33 0.30	1.72 4.179	0.568 1.254	0.665 0.929	1.463 2.044	0.895 0.79	1.69
Commercial	III	Starter Finisher	0.398 0.398	1.74 4.235	0.693 1.686	0.752 1.16	1.654 2.552	0.961 0.866	1.83

[+] Prices of computerised diets were increased by 22.48% to make up for the overhead charges which the commercial diets included. The figure was the average of overhead costs of four model manufacturing plants given in Ogunfowora, et al. 58

[++] Price of ₦2.20/kg. liveweight was used. It is the price used on the University Teaching and Research Farm Ibadan

TABLE 6.19: Summary of Net Revenue over feed costs per bird at varying costs of feed (varying costs of cassava) when cassava is replaced by maize in the diets

1 DIETS			2 Costs of feed at[+] varying prices of cassava (₦)			3 Feed Consumed kgs.	4 Value of feed consumed at varying cassava prices			6 Value of Weight gained	7 Net Revenue over feed costs at varying cassava prices (6-4)		
Cassava levels			₦220	₦170	₦120		₦220	₦170	₦120		₦220	₦170	₦120
0%	MC 1	Starter	0.256	0.256	0.25[illegible]	1.66	1.477	1.477	1.477	3.302	1.825	1.825	1.825
	MC 8	Finisher	0.237	0.237	0.237	4.438							
5%	MC 2	Starter	0.253	0.250	0.24[illegible]	1.743	1.551	1.532	1.512	3.317	1.766	1.785	1.805
	MC 9	Finisher	0.2[illegible]	0.230	0.2[illegible]	4.768							
10%	MC 3	Starter	0.25[illegible]	0.244	0.23[illegible]	1.65	1.473	1.431	1.393	3.295	1.824	1.864	1.902
	MC 10	Finisher	0.229	0.222	0.216	4.632							
15%	MC 4	Starter	0.249	0.240	0.230	1.65	1.462	1.405	1.346	3.401	1.939	1.996	2.055
	MC 11	Finisher	0.225	0.216	0.207	4.671							
20%	MC 5	Starter	0.251	0.239	0.226	1.56	1.410	1.336	1.261	3.406	1.996	2.070	2.145
	MC 12	Finisher	0.222	0.210	0.198	4.586							
25%	MC 6	Starter	0.253	0.237	0.222	1.64	1.267	1.182	1.099	2.999	1.732	1.817	1.900
	MC 13	Finisher	0.219	0.204	0.189	3.89							
30%	MC 7	Starter	0.256	0.237	0.219	1.48	1.124	1.033	0.945	2.220	1.096	1.187	1.275
	MC 14	Finisher	0.216	0.198	1.180	3.440							
COMMERCIAL I		Starter	0.33			1.72	1.822			3.507	1.69		
		Finisher	0.30			4.179							
COMMERCIAL III		Starter	0.393			1.74	2.379			4.205	1.83		
		Finisher	0.398			4.235							

+ Prices of computerised diets were increased by 22.48% to make up for the overhead charges which the commercial diets included. The fig. was the average of overhead costs of 4 model [illegible] plants given in [illegible], et al (56).

++ Price of ₦2.20/kg. liveweight was used. It is the price used on U.I. Teaching &

commercial I diet. It is pertinent to note here that cassava can be used up to the 20 percent level without adversely affecting the net revenue of the farmer.

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

7.1 Summary of the study

The main thrust of this study is concerned with the application of linear programming method to the problem of deriving least-cost and economically optimum diets for broilers under ad libitum feeding conditions. Whilst accomplishing these, other obviously related topics such as experimental designs for animal experiments, statistical problems of estimation arising from the structure of these experiments and basic biological relationships were dealt with. Another main objective of the study is to observe the possibility of substituting cassava flour for the traditional grains used in broiler feeds, and the economics of the resulting diets.

Chapter I defined the problem area as regards the deficiency of protein in the average Nigerian diet and the areas to be examined concerning livestock feeds and quality. The broiler industry was selected because of its short economic cycle which allowed several runs to be carried out to test various feed mixes. The objectives of the study as well as the plan of the thesis were stated also.

Chapter II gave a review of previous works in computerised poultry diets and a brief theory of the Linear Programming Technique. The model for least-cost ration formulation was expressed highlighting the problems of diet formulation.

Chapter III discussed the basic metrix in the linear programming model, the restrictions in the model and the solutions obtained by changing the restrictions in the matrix as desired.

In chapter IV, the experimental diets were discussed as well as the feeding trials. Certain statistical problems associated with the estimation of production functions from nutrition experiments were dealt with. This recognizes the presence of correlated errors arising from repeated observations on the same experimental unit and the random nature of feed intake resulting from ad libitum feeding. The data were therefore transformed appropriately to correct for such problems.

In chapter V, the comparison between cassava and the grains was made with respect to their characteristics and prices. Previous works on the use of cassava based diets for poultry were also reviewed.

Considering the fact that least-cost diets are not necessarily the most efficient in terms of animal performance, feeding trials were carried out with the aim of comparing their effects with those of the commercial diets on animal performance. Six feeding trials were carried out to compare the six different categories of computerised diets with some of the existing commercial diets. The first experiment tested eight starter diets with various combinations of two protein levels, two fibre levels and the inclusion of cassava at the five percent level. Comparison of these diets was based only on feed conversion efficiency and the diets with lower (24%) protein but high (5%) fibre levels proved better.

The second experiment was based on the first one in that two of the starter diets were selected and fed to the birds before testing two other computerised finisher diets on them. There was no significant differences (P ≤ 0.05) between the finisher diets and their combination with diet 7 (24% protein and 5% fibre) starter proved better than when combined with diet 2 starter (26% protein and 3% fibre). For experiments three to six, four groups of diets were formulated. The first group had starter diets in which cassava levels of 0, 5, 10. 15, 20, 25, and 30 percent were forced to replace guinea-corn (GCC1-GCC7). The second group also starter diets in which the same levels of cassava were forced to replace maize (MC1-MC7). The third and fourth groups had finisher diets in which 0, 5, 10, 15, 20, 25, 30, 35 and 40 percent levels of cassava were forced to replace guinea-corn (GCC8-GCC16) and Maize (MC8-MC16) respectively. Comparisons of these diets were based only on growth performance indices such as average total weight gain (ATG), average total feed intake (ATF), and feed conversion efficiency (FCE). No index of carcass quality was determined because it was not considered an important factor in our economy.

In experiments three and four in which cassava replaced guinea-corn and maize respectively in the diets at six different levels, analysis of variance tests showed that there were significant differences (P ≤ 0.05) in the diets. The least significant difference (lsd) statistical test proved commercial diet III to be the best whereas diet GCC 7 was poorest. Poor performance of diets GCC 6 & MC6 and GCC7 & MC7 was attributed to the high content of cassava in the diets which gave them a powdery nature and inhibited their consumption, Experiments five and six tested finisher diets in which cassava replaced guinea-corn and maize in the diets respectively. Analysis of variance tests showed that there were significant ($P \leq 0.05$) differences in the diets.

7.1.1: Regression Analysis

In chapter six of the study, the diets were further investigated to reveal how the principal nutrient components influenced animal performance. Regression analysis was therefore carried out on the experimental results obtained from the feeding trials for both starter and finisher computerised diets as well as the commercial diets. Analyses were on feed intake, single nutrient and nutrient combination effects on liveweight gain as well as the effects of the energy-based ingredients on liveweight gain. Liveweight gain was regressed on protein intake, energy intake, lysine intake and methionine plus cystine intake as single nutrients; then on protein and energy intake, lysine and methionine plus cystine intake as combined nutrients.

For the energy-based ingredients liveweight gain was regressed on maize intake and cassava intake, then guinea-corn intake and cassava intake. Both the quadratic and square root equations were fitted but the quadratic forms which performed better were selected as the lead equations in that they satisfied the laid down criteria.

Examination of the quadratic functional equations showed that feed intake is an important explanatory variable as far as liveweight gain is concerned and it explained more than half of the total variations in the performance of the birds.

For the single nutrient effects, protein, energy and the amino-acids proved to be important explanatory variables as far as liveweight gain is concerned. In the finishers, protein and energy explained less than half of the total variations whereas in the starters, they explained more than half of the total variations in the birds' performance.

For the nutrient combination effects, the functional equations showed that protein and energy and the amino-acids are significant explanatory variables in liveweight gains. Protein and energy combined explained 54 percent in the starters and 31 percent in the finishers whereas the amino-acids altogether explained 56 percent in the starters and 30 percent in the finishers. The low percentages explained by the nutrients was attributed to the fact that not all the nutrients were made available for the birds' metabolism.

Marginal analysis was carried out on some selected functions. The elasticity of production for energy and protein showed increasing returns to scale in the starter and finisher diets. The optimum broiler weight gain was determined as well as the quantities of maize, guinea-corn and cassava to obtain it. Production surfaces, isoquants and isoclines were calculated for selected functions.

7.1.2: Economic analysis of the diets

Using the results of the feeding trials, estimates of net revenue over feed costs for the different diets were computed. It was discovered that non-significant differences between diets was not synonymous with equal revenue yielding diets. For instance, diet 7 had better feed efficiency than diet 2 and diet 9 was better than diet 10 yet, combining starter diet 7 with finisher diets 9 and 10 gave the same revenue as combining starter diet 2 with finisher diets 9 and 10. In general, the computerised diets gave higher revenue than the commercial diets. For the diets in which cassava replaced guinea-corn and maize, the revenue accruing to the farmer decreased as the percentage cassava content of the diet increased. The revenue accruing from the diets in which cassava replaced guinea-corn are however higher than the revenues from diets in which cassava replaced maize. Diets containing up to 10 percent cassava had higher or equal revenue with the commercial diets. Diets with higher cassava levels are costlier because cassava is costlier than the grains. Profit levels were therefore obtained using different costs of diets as cassava price varies. When cassava was made to assume the same price with guinea-corn and maize, all the computerised diets except diets GCC 2 & 9 and GCC 7 and 14. MC 7 and 14 had higher net profit with commercial I diet. Net profits increased as cassava prices were reduced but diets GCC 7 and 14 and MC 7 & 14 gave the lowest net profit all the time.

Optimum marketing age determined suggested that broilers be sold at eleven weeks when there was maximum revenue over feed costs for diets containing cassava except diets GCC1 and 8, GCC2 and 9 and GCC 3 and 10.

7.2 Conclusions

The importance of the role played by the animal scientist and the economist is well illustrated by the biological and estimational problems involved in this study.

The results of this study reveal that any efforts to improve the returns to poultry, farmers must be focussed on the cost and quality of feeds. Particular attention must be paid to the ingredients included in the feed. Cheap sources of protein and oils such as soyabean and palm kernel meal have been used at high levels in this study to reduce the cost of feeds. There were diets in which groundnut cake was at very low levels (GCC 12-16) or even completely eliminated (GCC 8-11) and these diets did not perform poorer than those containing high levels of groundnut cake. Fish meal was not included in any of the computerised diets. Fish meal, apart from being an imported feed item, has experienced steep price increases and at certain periods had been unavailable.

The study lays emphasis on the importance of balancing the diets nutritionally using the technique of Linear Programming and taking into consideration the restrictions of the nutrients for each class of feed.

Cassava flour has been found to partly substitute for the grains without adversely affecting the performance of the birds. The high cost of cassava flour however reduces the net revenue to the farmer when it is used at high levels of 20 percent and above. If the cost of cassava flour can be reduced, then the feed costs would be reduced and the returns of the farmer would increase. Cassava grows well and uses marginal soils.

Efforts are being made to raise the yield further. Now that it has been proved to be usable up to 20 percent as energy source feed mixers in Nigeria can be said to have a waiting alternative in case the cheaper grain becomes less available.

Results of the regression analysis showed that protein, energy and some essential amino-acids such as lysine, methionine and cystine are important in the growth performance of broilers but they explained only a little proportion which raised a question on their availability for the birds' metabolism. Marginal analysis showed the maximum contribution of each nutrient but the extent to which one could substitute for the other depends on the costs of the sources of these nutrients and the needs of the birds.

7.3 Recommendations

From the results of experiments testing varying protein and fibre levels, practical broiler producers would be advised to start birds with diets of high protein and fibre levels and finish the birds on diets with lower protein percentage and high fibre content.

If the grains are to be replaced by cassava, the level of inclusion of cassava should not exceed 20 percent. This is the point at which revenue accruing to the farmer would not be adversely affected. Encouragement should be given to feed production in pellet form if cassava is to be used at higher levels.

It would be better if the use of guinea-corn can be stressed more in poultry diets than before. The experimental results proved that guinea-corn performs better than maize when combined with cassava in poultry diets. Government must now intensify research and production activities in respect of both cassava and guinea-corn. The results suggested also that broiler producers should sell off birds at eleven weeks of age if cassava substitutes for the grains. This is the point at which maximum revenue is obtained. The extent to which the weight and the quality of the poultry meat satisfy the requirements of consumers was however not taken into account. Government should fund research into the detailed chemical analysis of local feedstuff and the nutrient availability of the birds' metabolism,

7.4 Suggestions for further research

During the course of this study some diets were formulated in which soyabean meal was introduced as the protein source. The experiment was however not designed to measure the effects of using either soyabean meal only or groundnut cake as protein sources in the feed. It would be of interest to know which of the two ingredients is better or if perhaps they could be perfect substitutes.

In view of the various broiler breeds existing in the market now, it would be worthwhile to find out the effects of the various computerised feeds on the performance of each broiler breed including our local stock.

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APPENDIX A

Table 1: Records of average weekly feed intake and live-weight gains of birds fed ten starter diets for the period of six weeks

Diet		Av. Weekly (Kg) liveweight gain	Av. weekly (Kg) Feed Intake
LP	1	0.025	0.18
		0.050	0.21
		0.108	0.28
		0.223	0.39
		0.093	0.46
		0.127	0.49
LP	2		
		0.031	0.18
		0.046	0.21
		0.104	0.27
		0.246	0.41
		0.076	0.43
		0.102	0.49
LP	3		
		0.021	0.17
		0.042	0.23
		0.110	0.26
		0.157	0.40
		0.113	0.52
		0.078	0.56

APPENDIX A Continued.

Diet	Av. weekly (Kg) liveweight gain	Av. weekly (Kg) Feed Intake
LP 4	0.020	0.16
	0.051	0.19
	0.089	0.27
	0.114	0.37
	0.144	0.37
	0.167	0.50
LP 5	0.016	0.15
	0.039	0.21
	0.0[illegible]	0.24
	0.170	0.40
	0.136	0.47
LP 6	0.025	0.16
	0.038	0.23
	0.195	0.29
	0.153	0.47
	0.046	0.49
LP 7	0.023	0.18
	0.059	0.22
	0.110	0.31
	0.203	0.39
	0.136	0.49

APPENDIX A Continued.

Diet	Av. weekly (Kg) liveweight gain	Av. weekly (Kg) Feed Intake
LP 8	0.016	0.16
	0.038	0.22
	0.103	0.24
	0.167	0.38
	0.152	0.50
	0.064	0.47
Comm. I	0.027	0.17
	0.067	0.24
	0.121	0.32
	0.132	0.44
	0.154	0.50
	0.167	0.49
Comm. II	0.025	0.15
	0.037	0.17
	0.089	0.17
	0.118	0.34
	0.188	0.47
	0.198	0.47

APPENDIX B

Diet LP 2	Av. weekly liveweight (Kg). gain	Av. weekly Feed Intake (Kg)	Protein Intake (kg.)	Energy Intake (Kcals)	Percentage Protein
	0.022	0.17	0.044	4.864	26
	0.043	0.20	0.052	5.722	"
	0.038	0.20	0.052	5.722	"
	0.09	0.32	0.083	9.155	"
	0.11	0.32	0.083	9.155	"
	0.14	0.47	0.122	13.447	"
	0.02	0.17	0.044	4.864	"
	0.043	0.17	0.044	4.864	"
	0.11	0.21	0.055	6.008	"
	0.12	0.25	0.065	7.153	"
	0.12	0.34	0.088	9.727	"
	0.14	0.39	0.101	11.158	"
	0.02	0.15	0.039	4.292	"
	0.043	0.17	0.044	4.864	"
	0.10	0.17	0.044	4.864	"
	0.125	0.32	0.083	9.155	"
	0.175	0.33	0.086	9.443	"
	0.19	0.37	0.096	10.586	"
	0.018	0.17	0.044	4.864	"
	0.054	0.19	0.046	5.457	"
	0.087	0.20	0.052	5.722	"
	0.11	0.32	0.083	9.155	"
	0.17	0.34	0.088	9.727	"
	0.21	0.46	0.120	13.161	"

Energy level of feed = 2,861.4 Kcals/Kg.

APPENDIX B Contd.

Diet LP 7	Av. Weekly liveweight gain (Kg)	Av. Weekly Feed Intake (Kg)	Protein Intake (kg.)	Energey Intake (Kc als)	Percentage Protein
	0.022	0.16	0.038	4.598	24
	0.062	0.22	0.053	6.325	"
	0.11	0.22	0.053	6.325	"
	0.15	0.34	0.082	9.765	"
	0.20	0.35	0.084	10.052	"
	0.25	0.56	0.134	16.083	"
	0.022	0.16	0.038	4.598	"
	0.073	0.22	0.053	6.325	"
	0.11	0.28	0.067	8.042	"
	0.13	0.38	0.091	10.914	"
	0.21	0.43	0.10	12.35	"
	0.25	0.57	0.137	16.[illegible]	"
	0.02	0.16	0.038	4.598	"
	0.067	0.21	0.05	6.031	"
	0.095	0.25	0.06	7.180	"
	0.12	0.32	0.077	9.190	"
	0.21	0.37	0.089	10.626	"
	0.25	0.50	0.12	14.360	"
	0.017	0.16	0.038	4.598	"
	0.082	0.19	0.046	5.457	"
	0.11	0.20	0.05	5.744	"
	0.14	0.33	0.079	9.478	"
	0.16	0.34	0.082	9.765	"
	0.22	0.50	0.12	14.360	"

Energy level of feed = 2,871.9 Kcals/Kg.

APPENDIX B (Contd.)

Diet LP 9	Av. weekly liveweight gain (Kg)	Av. Weekly Feed Intake (Kg)	Protein Intake (kg.)	Energey Intake (Kcals)	Percentage Protein
	0.21	0.69	0.138	19.89	20
	0.23	0.68	0.136	19.60	"
	0.28	0.89	0.178	25.65	"
	0.26	0.81	0.162	23.34	"
	0.26	0.95	0.19	27.38	"
	0.22	0.52	0.104	14.99	"
	0.29	0.68	0.136	19.60	"
	0.29	0.89	0.178	25.65	"
	0.25	0.81	0.162	23.34	"
	0.28	0.77	0.154	22.19	"
	0.15	0.59	0.118	15.56	"
	0.26	0.70	0.140	20.17	"
	0.25	0.79	0.158	22.77	"
	0.21	0.77	0.154	22.19	"
	0.31	0.84	0.168	24.21	"
	0.16	0.54	0.108	15.56	"
	0.26	0.65	0.130	18.73	"
	0.19	0.71	0.142	20.46	"
	0.21	0.72	0.144	20.75	"
	0.21	0.77	0.154	22.19	

Energy level of feed = 2,882.4

APPENDIX B (Contd.)

Diet LF 10	Av. Weekly liveweight gain (Kg)	Av. Weekly Feed Intake (Kg)	Protein Intake (kg.)	Energy Intake (Kcals)	Per-centage Protein
	0.20	0.69	0.152	20.05	22
	0.21	0.65	0.143	18.89	"
	0.21	0.80	0.176	23.25	"
	0.25	0.81	0.178	23.32	"
	0.26	1.00	0.22	29.06	"
	0.16	0.57	0.125	16.56	"
	0.28	0.64	0.141	18.60	"
	0.22	0.75	0.165	21.50	"
	0.23	0.74	0.163	21.50	"
	0.38	0.96	0.211	27.90	"
	0.18	0.68	0.150	19.76	"
	0.25	0.67	0.147	19.47	"
	0.25	0.81	0.178	23.25	"
	0.28	0.80	0.176	29.06	"
	0.29	1.00	0.22	29.06	"
	0.15	0.50	0.110	14.53	"
	0.19	0.59	0.130	17.53	"
	0.22	0.67	0.147	19.47	"
	0.19	0.66	0.145	18.96	"
	0.22	0.78	0.172	22.67	"

Energy level of the feed = 2,906.2 Kcals/Kg.

APPENDIX B (Contd.)

Diet	Av. Weekly live-weight gain (Kg)	Av. Weekly Feed Intake (Kg)
Comm.I		
	0.025	0.15
	0.04	0.17
	0.08	0.17
	0.11	0.34
	0.17	0.47
	0.20	0.46
	0.035	0.17
	0.08	0.18
	0.12	0.35
	0.18	0.48
	0.21	0.50
Comm. II		
	0.027	0.17
	0.067	0.24
	0.121	0.32
	0.132	0.44
	0.154	0.50
	0.167	0.49
	0.026	0.17
	0.065	0.25
	0.11	0.45
	0.12	0.50
	0.14	0.50
	0.16	0.52

APPENDIX B (Contd.)

Diet	Av. Weekly live-weight gain (Kg)	Av. Weekly Feed Intake (Kg)
Comm. I Finisher		
	0.20	0.62
	0.22	0.71
	0.25	0.75
	0.28	0.81
	0.30	0.96
	0.20	0.65
	0.21	0.75
	0.23	0.81
	0.24	0.82
	0.27	0.97
Comm. II Finisher	0.16	0.68
	0.19	0.69
	0.21	0.74
	0.24	0.80
	0.26	1.00
	0.16	0.67
	0.19	0.68
	0.22	0.72
	0.25	0.81
	0.25	0.96

APPENDIX C   Starters (3rd Expt.)

Diets	Weight Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Methionine plus cystine Intake (gms.)
1.	828.8	1837.3	441	5328.2	2.3	1.433
	681.5	1903.2	456.8	5519.3	2.38	1,484
2.	667.7	1700.6	408.1	4931.7	2.13	1,326
	671.6	1661.2	398.7	4817.5	2.08	1,279
3.	760.6	1812.9	435.1	5257.4	2.27	1,396
	813.5	1884.2	542.2	5464.2	2.36	1,450
4.	760.6	1878.9	451	5448.8	2.35	1.446
	756.5	1885.4	452.5	5467.7	2.36	1.451
5.	1005	2053.2	492.8	5954.3	2.57	1.451
	521.3	1903.3	456.8	5519.6	2.38	1.465
	521.3	1903.3	456.8	5519.6	2.38	1.465
6.	755.7	1879.5	451.1	5450.6	2.35	1.428
	779.5	2000	480	5800	2.50	1,520
7.	803	2017.9	484.3	5851.9	2.52	1.513
	710.9	1871.2	449.1	5426.5	2.66	1,403
8.	616.7	1871	449	5425.9	2.66	1,403
	647.9	1724.4	413.9	5000.8	2.16	1,362
9.	852.5	1841.5	442	5340.4	2.54	1,436
	754.9	2069.6	496.7	6001.8	2.86	1.614
10.	803.5	1846.6	445.2	5355.1	2.40	1.440
	724.2	2120.9	509	6150.6	2.76	1.654

APPENDIX C. Starters (3rd Expt.) Contd.

Diets	Weight Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Methionine plus cystine Intake (gms.)
11.	803.5	1820.2	436.8	5278.6	2.28	1.419
	692.4	1951	468.2	5057.9	2.44	1.521
12.	646.9	1770.5	424.9	5134.5	2.21	1.381
	681.5	1858.3	446	5389.1	2.32	1.449
13.	493.3	2050.4	492.1	5946.2	2.56	1.599
	446.2	1926	462.2	5585.4	2.41	1.502
14.	746.7	1703.7	408.9	4940.7	2.13	1.294
	656.7	1874.7	450	5436.6	2.34	1.424
Comm.1	747.9	2007.2	481.7	5436.6		-
	762.4	2079.4	477.1			-
Comm.III	883.6	2054.2				
	844.1	1919.6				

APPENDIX C Cotd. Starters (4th Expt.)

	Weight Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Methionine + Cystine Intake (gms.)
1.	557.4	1215.3	291.7	3524.4	1.52	0.948
	627.6	1377.6	330.6	3995	1.72	1.060
2.	370	1136.7	272.8	3296.4	1.42	0.875
	536.7	1395	334.8	4045.5	1.74	1.074
3.	536.2	1295.7	311	3757.5	1.62	0.997
	540	1423.7	341.7	4128.7	1.78	1.096
4.	472.7	1688.4	405.2	4896.4	2.11	1.300
	357.9	1303.7	312.9	3780.7	1.63	1.003
5.	348.3	1253.9	300.9	3636.3	1.57	0.965
	351.7	1412.2	338.9	4095.4	1.77	1.087
6.	450	1346.7	323.2	3905.4	1.68	1.010
	468.4	1187.7	285	3444.3	1.48	0.914
7.	208.1	969.1	232.6	2810.4	1.21	0.726
	213.5	992.3	238.2	2877.7	1.24	0.744
8.	585	1533.3	368	4446.6	2.18	1.150
	592.4	1501.4	360.3	4354.1	2.13	1.186
9.	571.4	1563.6	375.3	4534.4	2.16	1.219
	505.2	1481.5	355.6	4296.4	2.04	1.155

APPENDIX C. Contd. Starter (4th Expt.)

	Weight Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Methionine + Cystine Intake (gms.)
10.	581.9	1339.9	321.6	3885.7	1.74	1.045
	458.1	1293	320.5	3749.7	1.68	1.008
11.	649.9	1335.4	320.5	3872.7	1.67	1.041
	514.7	1488.7	357.3	4317.2	1.86	1.163
12.	551.7	1436.8	344.8	4166.7	1.78	1.120
	416.7	1275.8	306.2	3699.8	1.59	1.095
13.	333.2	1281	307.4	3714.9	1.60	0.999
	367.8	1309.6	314.3	3797.8	1.64	1.021
14.	354.6	1114.7	267.5	3232.6	1.40	0.847
	345.9	1216.7	292.0	3528.4	1.52	0.904
Comm.I	587.1	1114.7	339.1			
	561.3	1377.4	330.6			
C. II	648.3	1451.6				
	632.2	1518.8				

APPENDIX C. Contd. Finishers (4th Expt.)

	Wt. Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Cystine + Methionine Intake (gms.)
1.	855	4169.5	876.4	11674.6	5.42	3.293
	797	3254.4	684.1	9112.3	4.23	2.571
2.	752	3918.9	815.1	10972.9	5.10	3.096
	660	3357.4	698.3	9400.7	4.37	2.652
3.	716.5	3929.6	803.6	11002.9	5.11	3.065
	863.6	3283.5	671.5	9193.8	4.27	2.561
4.	948.3	3711.6	746	10392.5	4.78	2.858
	779.2	3461.[illegible]	695.[illegible]	9692.5	4.47	2.665
5.	937.3	4168.5	[illegible].5	11671.8	5.42	3.210
	593.3	3506.1	712.8	9857.1	4.56	2.70
6.	919.6	3952.4	806	11066.7	5.14	3.043
	446.7	3142	635.9	8797.6	4.08	2.419
7.	682.5	4528.3	912.9	12679.2	5.89	3.419
	589.3	3587.9	723.3	10046.1	4.66	2.763
8.	726.7	4370	878.4	12236	5.68	3.321
	412.1	3487.7	704	9765.6	4.53	2.651
9.	752.8	4212.8	863.[illegible]	11795.8	5.48	3.202
	392.9	3390.1	695	9492	4.41	2.577
10.	850	4195	892.3	11746	5.45	3.34
	644	343.7	668.7	8802.4	4.09	4.531

APPENDIX C. Contd. Finishers (4th Expt.)

	Wt. Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Cystine + Methionine Intake (gms.)
11.	735	4095	864	11466	5.32	3.235
	650	3492.1	736.8	9777.9	4.54	2.759
12.	862.4	4181.6	882.3	11708.5	5.44	3.303
	674.7	3415.3	720.6	9562.8	4.44	2.698
13.	910	3830	841.1	10724	4.98	3.026
	454.2	3150	691.7	8820	4.10	2.489
14.	931.6	3668.6	807.1	10272.1	4.77	2.898
Comm.I	793.8	3689.9	811.8	10331.7	4.80	2.915
	1085	3930	903.9			
C.III	685.3	3786.8	871			
	1020	3890				
	750	3317.8				
15.	1020	4006	881.3	11216.8	5.21	3.165
	886.8	3773.8	830.2	10566.6	4.91	2.981
16.	454.2	3776.9	830.9	10575.3	4.91	2.984
	512.3	3118.5	686.1	8731.8	4.05	2.984
17.	840	3440	756.8	9632	4.47	2.683
	760	3200	704	8960	4.16	2.496
18.	990	3565	784.3	9982	4.63	2.781
	810	3230	710.6	9044	4.20	2.519

APPENDIX C. Contd. Finishers (3rd Expt).

Diets	Weight Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Methionine + Cystine Intake (gms.)
1.	1173.8	5452.4	1146.1	15266.7	7.09	4307
	1318.5	5296.8	1113.4	14831	6.89	4184
2.	787.7	5624.2	1169.8	15747.8	7.31	4443
	1021	5320.8	1106.7	14893.2	6.92	4203
3.	1151.1	5373.7	1098.9	15046.4	7.00	4200.
	1130.9	5373.7	10989.9	15046.4	6.99	4191
4.	1000	5180.4	1041.3	14505.1	6.68	3988
	700	4594.3	923.5	12364	5.93	3537
5.	1000	5436.7	1105.3	15222.6	7.07	4186
	987.2	5289.6	1075.4	14810.9	6.88	4073
6.	947.4	5300.4	1072.8	14841.1	6.89	4081.
	1044.8	5233.4	1059.9	14653.5	6.80	4029.
7.	744.4	5517.7	1112.4	15449.6	7.17	4248
	890	5516.1	1112.1	15445.1	7.17	4247
8.	975.9	5674.3	1140.5	15885	7.38	4312.
	1105.3	5231	1051.4	14646.8	6.80	3975
9.	837.4	5301.7	1086.6	14844.8	6.89	4029
	945	5630.7	1154.3	15766	7.32	4279
10.	894.8	5222.4	1110.6	14622.7	6.79	4125
	1171.4	5192.8	1104.5	14539.8	6.75	4102
11.	947.4	5833.7	[illegible]	[illegible]	7.58	4608
	1021.3	5652.8	1192.7	15827	7.35	4465

APPENDIX C. Contd. Finishers (3rd Expt.)

Diets	Weight Gain (gms.)	Feed Intake (gms.)	Protein Intake (gms.)	Energy Intake (Calories)	Lysine Intake (gms.)	Methionine + Cystine Intake (gms.)
12.	1021.3	5624.5	1186.8	15748.6	7.31	4443
	863.6	5307.8	1120	14861.8	6.90	4193
13.	1191.6	5541.2	1216.8	15515.4	7.20	4377
	1010.9	6161.5	1353.1	17252.2	8.01	4867
14.	1004.3	5359.3	1179.1	15006	6.97	4233
Comm.I	1166.7	5624.9	1237.5	[illegible]	7.31	4443
	1000	4983.5	1146.2			
	947.4	4463	1031.[illegible]			
C. III	1210.5	4413.3				
	1642	5317.7				

APPENDIX D Starters (3rd Expt.)

	Weight Gain (gms.)	Feed Intake (gms.)	G. Corn (gms.)	Maize (gms.)	Cassava Level %	Cassava Intake (gms.)
1.	828.8	1837.3	1017.1	-	0	0
	681.5	1903.2	1053.6	-	0	0
2.	667.7	1700.6	836.0	-	5	85.0
	671.6	1661.2	816.7	-	10	83.1
3.	760.6	1812.9	763.1	-	10	181.3
	813.5	1884.2	793.1	-	10	188.4
4.	760.6	1878.9	658.2	-	15	281.8
	756.5	1853.2	650	-	15	278.3
5.	1005	2053.2	574.3	-	20	410.6
	521.3	1903.3	532.4	-	20	380.7
6.	755.7	1879.5	393.0	-	25	469.9
	779.5	2000	418.2	-	25	500.0
7.	803	2017.9	295.4	-	30	605.4
	710.9	1871.2	273.9	-	30	561.4
8.	616.7	1871	-	1043.[illegible]	[illegible]	0
	647.9	1724.4	-	96[illegible]	[illegible]	0
9.	852.5	1841.5	-	90[illegible]	5	92.1
	754.9	2069.6	-	1016.4	5	103.5
10.	803.5	1846.6	-	773.0	10	184.7

APPENDIX D Contd. Starters (3rd Expt.)

	Weight Gain (gms.)	Feed Intake (gms.)	G. Corn	Maize (gms.)	Cassava Level %	Cassava Intake (gms.)
11.	803.5	1820.2	-	629.2	15	273.0
	692.4	1951	-	674.5	15	292.7
12.	646.9	1770.5	-	482.1	20	354.1
	681.5	1858.3	-	506.0	20	371.7
13.	493.3	2050.4	-	411.5	25	512.6
	446.2	1926	-	386.6	25	481.5
14.	746.7	1703.7	-	247.9	30	511.1
	656.7	1874.7	-	272.8	30	562.4

APPENDIX D Contd. Finishers 4th Expt.

	Weight Gain (gms.)	Feed Intake (gms.)	G. Corn (gms.)	Maize	Cassava Level %	Cassava Intake (gms.)
1.	855	4169.5	2343.7	-	0	0
	797	3254.4	1829.3	-	0	0
2.	752	3918.9	1979.4	-	5	196.0
	660	3357.4	1695.8	-	5	167.9
3.	716.5	3929.6	1762.8	-	10	393.0
	863.6	3283.5	1473.0	-	10	328.4
4.	948.3	3711.6	1457.9	-	15	556.7
	779.2	3461.6	1359.7	-	15	519.2
5.	937.3	4168.5	1353.5	-	10	833.7
	593.3	3506.1	1138.4	-	20	701.2
6.	919.6	3952.4	1040.7	-	25	988.1
	446.7	3142.0	827.3	-	25	785.5
7.	682.5	4528.3	914.3	-	30	1358.5
	589.3	3587.9	724.4	-	30	1076.4
8.	726.7	4370	614.0	-	35	1529.5
	412.1	3487.7	490.0	-	35	1220.7
9.	752.8	4212.8	276.8	-	40	1685.1
	392.9	3390.1	222.7	-	40	1356.0

APPENDIX D Contd. Finishers 4th Expt.

	Weight Gain (gms.)	Feed Intake (gms.)	G. Corn (gms.)	Maize (gms.)	Cassava Level %	Cassava Intake (gms.)
10.	850	4195	-	2257.3	0	0
	644	3143.7	-	1691.6	0	0
11.	862.4	4181.6	-	1749.6	5	204.8
	650.8	3492.1	-	1676.9	5	174.6
12.	862.4	4181.6	-	1749.6	10	418.2
	674.7	3415.3	-	1423.0	10	341.5
13.	910	3830	-	1280.8	15	574.5
	454.2	3150	-	1053.4	15	472.5
14.	931.6	3668.6	-	996.8	20	733.7
	793.8	3689.9	-	1002.6	20	738.0
15.	1020	4006	-	841.3	25	1001.5
	886.8	3773.8	-	792.5	25	943.5
16.	454.2	3776.9	-	560.0	30	133.1
	512.3	3118.5	-	462.8	30	935.6
17.	840	3440	-	298.6	35	1204.0
	760	3200	-	277.8	35	1120.0
18.	990	3565	-	89.8	40	1426.0
	810	3230	-	81.4	40	1292.0

APPENDIX D Contd. Starters 4th Expt.

	Weight Gain (gms.)	Feed Intake (gms.)	G. Corn (gms.)	Maize (gms.)	Cassava Level %	Cassava Intake (gms.
1.	557.4	1215.3	672.8	-	0	0
	627.6	1377.6	762.6	-	0	0
2.	370	1136.7	558.8	-	5	56.8
	536.7	1395	685.8	-	5.	129.6
3.	536.2	1295.7	545.4	-	10	129.6
	540	1423.7	599.2	-	10	142.4
4.	472.7	1688.4	591.5	-	15	253.3
	357.9	350.7	456.7	-	15	195.6
5.	348.3	1253.9	350.7	-	20	250.8
	351.7	1412.2	395.0	-	20	282.4
6.	450	1346.7	281.6	-	25	336.7
	468.4	1187.7	248.3	-	25	296.9
7.	208.1	969.1	141.9	-	30	290.7
	213.5	992.3	145.3	-	30	297.7
8.	585	1533.3	-	855.1	0	0
	592.4	1501.4	-	837.3	00	0
9.	571.4	1563.6	-	767.9	5	78.18
	505.2	1481.5	-	727.6	5	74.10
1010.	581.9	1339.9	-	500.9	10	134.0
	458.1	1293	-	541.3	10	129.3
11.	649.9	1335.4	-	461.7	15	200.3
	514.7	1488.7	-	514.6	15	223.3
12.	551.7	1436.8	-	391.2	20	287.4
	416.7	1275.8	-	347.4	20	255.2
13.	333.2	1281	-	257.1	25	320.3
	367.8	1309.6	-	262.8	25	327.4
14.	354.6	1114.7	-	162.2	30	334.4
	345.9	1216.7	-	177.0	30	365.0

APPENDIX D Contd. Finishers (3rd Expt.)

	Weight Gain (gms.)	Feed Intake (gms.)	G. Corn (gms.)	Maize (gms.)	Cassava Level %	Cassava Intake (gms.)
1.	1173.8	5452.4	3064.8	-	0	0
	1318.5	5296.8	2977.3	-	0	0
2.	787.7	5624.2	2840.4	-	5	281.2
	1021	5320.8	2687.5	-	5	266.0
3.	1151.1	5385.3	2415.9	-	10	538.5
	1130.9	5373.7	2410.6	-	10	537.4
4.	1000	5180.4	2034.9	-	15	777.1
	700	4594.3	1804.6	-	15	689.1
5.	1000	5436.7	1765.3	-	20	1087.3
	987.2	5289.6	1717.5	-	20	1057.9
6.	947.4	5300.4	1395.6	-	25	1325.1
	1044.8	5233.4	1378.0	-	25	1308.4
7.	744.4	5517.7	1114.0	-	30	1655.3
	890	5516.1	1113.7	-	30	1654.8
8.	975.9	5674.3	-	3053.3	0	0
	1105.3	5231.0	-	2814.8	0	0
9.	837.4	5301.7	-	2545.9	5	265.1
	945	5630.7	-	2793.9	5	281.5
10.	894.8	5222.4	-	2185.1	10	522.2
	1171.4	5192.8	-	2172.7	10	519.3
11.	947.4	5833.7	-	1950.8	15	875.1
	1021.3	5652.8	-	1890.3	15	847.9
12.	1021.3	5624.5	-	1528.2	20	1124.9
	863.6	5307.8	-	1442.1	20	1061.6
13.	1191.6	5541.2	-	1163.7	25	1385.3
	1010.9	6361.5	-	1293.3	30	1540.4
14.	1004.3	5359.3	-	795.3	30	1607.8
	1166.7	5624.9	-	834.7	30	1687.5