EVALUATION OF BREWERS' SORGHUM RESIDUE FOR GROWTH AND REPRODUCTION IN RABBITS

BY

MEDINAT ELIZABETH PRAISE ABDULMALIK

B.Sc. (AGRICULTURE) 1988

AHMADU BELLO UNIVERSITY, ZARIA.

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE.

DEPARTMENT OF ANIMAL SCIENCE

FACULTY OF AGRICULTURE.

JUNE, 1997

COPYRIGHT STATEMENT

This thesis or any part thereof must not be reproduced in any form without the written permission of the Post Graduate School, Ahmadu Bello University, Zaria or the author.

DIGITIZED

DECLARATION

This is to certify that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All quotations are indicated and the sources of information are specifically acknowledged by means of references.

M.E.P. ABDULMALIK

19/12/97

DATE

CERTIFICATION

This thesis "Evaluation of brewers' sorghum residue for growth and reproduction in rabbits" by M.E.P. Abdulmalik meets the regulations governing the award of the degree, Master of Science of Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

Prof. A.O. Aduku
Chairman,
Supervisory Committee

Date: 19/12/97

19/12/97

Prof. S.O. Ogundipe
Member,
Supervisory Committee

Date: 19/12/97

Prof. T.F. Balogun
Member,
Supervisory committee

Date: 19/12/97

Dr. J.P. Alawa
Head,
Dept. of Animal Science

Date: 19/12/97

Prof. J.O. Olayemi
Dean,
Post Graduate School,
Ahmadu Bello University,
Zaria.

Date: 17/8/98

Prof. C.O. Obioha
External Examiner,
University of Nigeria,
Nsukka.

Date: _____

DEDICATION

This thesis is dedicated to

THE HOLY SPIRIT,

my ever present help, companion, partner

and supervisor, without whom I would not have made it.

ACKNOWLEDGEMENT

My profound gratitude goes to my major supervisor, Professor A.O. Aduku and the other members of my supervisory committee, Professors T.F. Balogun and S.O. Ogundipe, for their immence contributions towards the successful completion of this research. I am also indepted to the Director, NAPRI, Dr. M.S. Kallah, the former Director, NAPRI, Professor E.O. Oyedipe, the Head, Rabbit Research Unit, NAPRI, Mrs. G.T. Erakpotobor and the Head, Department of Animal Science, Dr. J.P. Alawa, for their invaluable contributions towards the successful completion of my resaerch work and defence of the Thesis.

My sincere thanks to the Technical officer, Alh. M.H. Idris and other staff members of the Rabbit Research Unit, NAPRI, Shika for their assistance throughout the duration of this research work. This is also extended to the staff of Poultry Research Programme, the Feedmill, the Central laboratory, NAPRI, Shika and the staff of Department of Animal Science, Faculty of Agriculture, A.B.U., Zaria for their cooperation and various assistance during the course of this work. I am particularly grateful to Mr. I.A. Adeyinka for the analyses of the data of this research work.

My special thanks to my Daddy in the Lord, Rev. David Bakare, and Pastors Thomas Shikaan, Paul Bolorunduro and Sam Abolaji of Jesus is Life World Outreach Ministries, Zaria, for

their prayers and encouragement throughout this study. I am also grateful to Dr. & Mrs. O.O. Oni, Mrs. I.A. Adeyinka, Jolaade Adegbite, Bunmi Oladimeji, Enoch Aduli, Raphael Afolayan, Kemi Ogunlade, Taye Amos, Taiye Olugbemi, Emmanuel Ikanni and all my other friends for their much needed encouragement and prayer support during this work.

I deeply appreciate the care and support of members of my family particularly my mum, Mrs. Janet Abdulmalik, my brothers, Umar and Ibrahim, my sisters, Hajara and Hannatu, my uncles, Mark Alabi, Segun Adewole, Kayode Garr and their families. God bless you all and reward your labour of love. Finally, all my thanks goes to God Almighty, my loving Father for His grace and strength to continue even in the face of discouragement. He has taught me to know that "all things work together for good to them that love God and are called according to His purpose" (Romans 8:28). To Him alone be all glory, praise and honour for evermore, Amen.

TABLE OF CONTENTS

		PAGE
TITLE PAGE	.....	i
COPYRIGHT STATEMENT	.....	ii
DECLARATION	.....	iii
CERTIFICATION	.....	iv
DEDICATION	.....	v
ACKNOWLEDGEMENT	.....	vi
TABLE OF CONTENTS	.....	viii
LIST OF TABLES	.....	xi
ABSTRACT	.....	xii
CHAPTER ONE: INTRODUCTION	.....	1
CHAPTER TWO: LITERATURE REVIEW	.....	5
2.1 The Rabbit: Origin and Distribution	..	5
2.1.1 The Rabbit's Potential	.....	6
2.2 Agro-industrial by-products	.....	10
2.2.1 The brewing process	.....	11
2.2.2 Description of some brewery by-products		12
2.3 Nutrient content of brewers' dried grain		15
2.4 Utilization of brewers' dried grains in non-ruminant diets	.....	18
2.4.1 Utilization of brewers' dried grains in swine diets	.....	18
2.4.2 Utilization of brewers' dried grains in poultry diets	.....	21
2.4.3 Utilization of brewers' dried grains by rabbits	.....	24

2.4.4 Utilization of sorghum beer residue or BKT waste 25

2.5 Problems associated with feeding brewers' dried grains 28

2.6 Industrial utilization of sorghum in Nigeria 29

2.7 Tannin in sorghum and sorghum products 31

2.8 Crude fibre digestion and utilization in rabbits 32

2.8.1 Digestibility of crude fibre in rabbits 33

2.8.2 The role of fibre in rabbit nutrition . 34

CHAPTER THREE: EFFECT OF GRADED LEVELS OF BREWERS' SORGHUM RESIDUE ON GROWTH PERFORMANCE OF WEANER RABBITS.

3.1 Abstract 37

3.2 Introduction 39

3.3 Material and Methods 41

3.4 Results and Discussion 43

3.5 Conclusion 56

CHAPTER FOUR: EFFECT OF GRADED LEVELS OF BREWERS' SORGHUM RESIDUE ON REPRODUCTIVE PERFORMANCE OF BREEDING DOES.

4.1 Abstract 62

4.2 Introduction 63

4.3 Materials and Methods 65

4.4 Results and Discussion 66

4.5 Conclusion 70

ABSTRACT

Two experiments were conducted to evaluate the feeding value of brewers' sorghum residue (BSR) in rabbit diets. The chemical composition of brewers' sorghum residue used in these experiments was also determined.

In Experiment 1, weaned rabbits of about six weeks old with an average initial weight of 617g, were fed diets containing 0, 10, 20, 30 and 40% BSR while in experiment 2, breeding does of average initial weight of 1945kg, were fed diets containing 0, 7.5, 15, 22.5 and 30% BSR. The diets in each study were iso-nitrogenous but not isocaloric. At the end of the six weeks weaner trial, carcass parameters were measured. A digestibility trial was also carried out to measure the nutrient digestibility coefficients of the diets.

The result of the chemical analysis showed that BSR contained, on dry matter basis, 30.16% crude protein, 11.82% ether extract, 12.93% crude fibre and 2.51% ash. The contents of calcium, phosphorus and soluble tannins were 0.14%, 0.43% and 6.02% respectively. The gross energy content was found to be 4.92kcal/g.

The results obtained from the study with the weaner rabbits showed significant ($P<0.05$) effects of treatments on daily weight gain, daily feed intake, feed conversion ratio, feed cost per kilogram and feed cost per kilogram live weight

gain. Weight gain was significantly higher (P<0.05) at 20% BSR level when compared with the control but reduced significantly (P<0.05) at higher levels of inclusion. Feed intake decreased significantly (P<0.05) as the level of BSR increased in the diet. Feed conversion ratio also became significantly (P<0.05) poorer at higher levels of BSR begining from the 30% level of BSR inclusion. Increase in dietary level of BSR significantly (P<0.05) lowered feed cost/kg. Feed cost/kg live weight gain reduced significantly (P<0.05) up to 20% BSR level then increased thereafter. Mortality was not significantly (P>0.05) affected by dietary treatments.

Dressing percentage, gut length and abdominal fat content significantly decreased (P<0.05) while gut plus caecum weight increased as dietary BSR level increased when compared with the control. There were however no significant (P>0.05) effects of treatment on liver and edible organ weights (liver, heart, kidney) . The digestibilities of DM, CP, CF, EE, and ash were not significantly (P>0.05) affected by increase in the levels of BSR in the diet.

The results of the study with breeding does showed no significant (P>0.05) effect of treatment on gestation length, litter size at birth, litter birth weight, average birth weight and feed cost/kg of the feed. Feed intake significantly (P<0.05) reduced as level of BSR increased in the diet. Gestation weight gains increased significantly (P<0.05) with increasing BSR levels up to 15% after which it

decreased.

The results of these studies suggest that brewers' sorghum residue can be economically fed in rabbit diets at levels up to 20% and 15% for weaners and breeding does respectively. These levels increased weight gain, reduced cost of feeds, maximized profit and gave no detrimental effects on performance.

CHAPTER ONE

1.0 GENERAL INTRODUCTION

The present trend of inflation worldwide has become a source of concern for livestock owners as such inflatory trends often have adverse effects on livestock feeds and hence on cost of producing livestock and livestock prooducts. Hence, there has been an increase in the competition between man and his livestock for scarce grain resources leading to an acute problem of feed shortages typifying the economy of many of the developing countries. According to Babatunde (1986), one major solution to this problem is to drastically increase the production of those ingredients commonly used in livestock feeds such as maize, groundnut and others, so as to cater for the needs of both humans and animals. Where this cannot be achieved, attempts should be made to source for alternative feedstuffs for livestock. One characteristic of such feedstuffs should be its non-competitive usage with man. Most of the alternative feedstuffs identified so far fall into the category of agro-industrial by-products such as brewers' spent grains from the breweries. Thousands of tons of brewers' spent grains are turned out annually from the many breweries in the country, with only a small fraction been used by animals particularly for monogastric rations.

Brewers' dried grains are defined as the dried extracted residue of barley malt alone or in mixture with other cereal

grains or grain products resulting from the manufacture of wort or beer (Adebowale and Ademosun, 1981). According to Bello (1984) brewers' grains and brewers' yeast are the main by-products of the brewing industry in Nigeria available for use in livestock feeding. Most breweries do not have facilities for drying this product and therefore contract out the disposal of the wet product to farmers or agents who dry them for livestock feeding. Brewers' grains has a relatively high protein content (23.62% CP) compared with maize (10.15% CP). It however does not contain a good balance of amino acids. They are rich sources of essential fatty acids and vitamins, especially B-complex vitamins (Singh, 1988) and being a by-product of fermentation, contains unidentified growth factors (Babatunde *et al.*, 1975). Due to its high content of crude fibre (over 20%), barley-based brewers' dried grains have not been widely used in the diets of monogastric animals particularly poultry (Nelson, 1984). It is however a valuable feedstuff for ruminants (Umunna, 1980; Adebowale and Ademosun, 1981; Umoh *et al.*, 1982; Udedibie, 1984).

Much work have been carried out on barley-based brewers' dried grains with little or no work on spent grains derived from other sources such as from the production of the local beer known as "burukutu or BKT". The production of this by-product, also known as "sorghum beer residue", is derived from the utilization of indigenous cereals such as sorghum used solely or in combination with other cereal grains in the

production of the local beer (Dogari, 1985).

Following the ban on the importation of barley in 1988, the brewing industry in Nigeria began to utilize indigenous cereals such as maize and sorghum for the production of lager beer (Aisien, 1989). The production of beer from 100% sorghum however, is entirely a new concept in Nigeria. This has resulted in the production of a by-product referred to in these studies, as "brewers' sorghum residue". This by-product looks fibrous and more nutritious than the conventional barley-based by-product. According to Udedibie and Emenalom (1993), the striking features of the maize/sorghum based brewers grains are its relatively low fibre (12.42%) and very high protein (28.64%) contents. This low fibre content significantly deviates from the crude fibre content of the conventional barley-based brewers' grains which ranges from 19-22% (Babatunde *et al.*, 1975; Alawa *et al.*, 1988; Maertens *et al.*, 1990). It's crude protein content of 28.64% compares favourably with reported values for barley-based dried brewers grains which range from 24-31% (NRC, 1978; Chase *et al.* 1981). Udedibie and Emenalom (1993) have successfully incorporated about 20% of this maize/sorghum residue into the diets of poultry without any significant defects in production. Other advantages of this by-product is that it is relatively cheaper than maize and it does not require much additional processing such as grinding, before incorporation into the diets of livestock. Its increased usage in livestock rations will also

help to preserve the ecosystem from further pollution resulting from its disposal. Though the product is fibrous and would appear best suited for feeding ruminant animals, advantage should be taken of its fairly rich source of fermentable products, particularly the B-vitamins, by including it in diets for rabbits which can handle high fibre diets due to their well developed hind gut. If optimal level of inclusion could be established, it might not only serve as a source of B-vitamins, it might also contribute some protein and energy and hence reduce the level of maize and protein sources that are presently being included in the diets of rabbits. Sorghum based brewers' dried grains however must be used with caution in diets of livestock as this has been shown to contains the anti-nutritive tannin, which binds proteins (Dogari, 1985; Kumar and Singh, 1984) and reduces amino acid availability (Nelson *et al.*, 1975).

This study was therefore designed to:

i. investigate the utilization of brewers' sorghum residue as an alternative feed source for rabbits

ii. determine the effects of using graded levels of brewers' sorghum residue in the diets of weanling and pregnant rabbits with the view to establishing the optimal levels of inclusion in rabbit diets.

iii. evaluate the economic benefits of using brewers' sorghum residue in rabbit diets.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 THE RABBIT: ORIGIN AND DISTRIBUTION

The domestic rabbit, a descendant of the European rabbit, *Oryctolagus cuniculus*, is the domesticated form of the only species of the genus Oryctolagus (old world rabbit). The European hare (*Lepus europeus*) in contrast, belong to one of 22 species of the genus Lepus (genuine hares). The first step towards domestication was practiced by the Romans, who held rabbits in enclosures called "Leporaria" (Schlolaut, 1985). This form of production provided a constant supply of fresh meat, as well as foetus and newborn, which they considered delicacies. Thus originated the distribution of the rabbit to other middle and eastern European countries. Now, the broad scope of species of wild rabbit covers nearly all climatic regions of the earth.

The two main producers recognised in Africa are Ghana and Egypt, both with 7,000 - 8,000 tonnes of carcasses a year. Algeria and Sudan come far behind with 1,000-2,000 tonnes a year (Lebas *et al.*, 1986). Although commercial production exists in these countries, most rabbitries are family owned, with a part of the output going to the market. The national rabbit production development programme in Ghana, for example, proposes a system where small family units keep only 3-6 breeding animals, so they can be fed on what is grown locally

- forage, cassava etc. and produce surplus animals for sale.

The domestication and rearing of rabbit in Nigeria dates far back to the colonial era when rabbits were introduced through missions and the agricultural service (FDLPCS, 1992). Rabbit production is now well established in Nigeria. Rabbits can be found in scattered locations throughout the country.

In contrast to larger species, where slow turnover of stock creates management problem, farmers generally are begining to appreciate the rearing of rabbits as an effective intervention for raising the animal protein intake in many rural areas.

2.1.1 THE RABBIT'S POTENTIAL

The advantages offered by the rabbit, in comparison to other livestock, make it a potential livestock species for alleviating the animal protein shortages in the country. Schlolaut (1985) summarises the positive characteristics of the rabbits as follows:

a) The meat production per doe is higher than in all other herbivorous farm animals, due to the high rate of reproduction. In countries where the skin is also eaten after removal of the hair, the slaughter yield rises from 60% to 75%. The carcass production per female/year is thereby increased from 25 to 35 times the doe's weight. Table 1 below gives the meat production of various domestic species.

Table 1: Meat production of various domestic species in percentage of the adult weight of female animals.

Species	Weight Adult Females,	Young Reared per year kg.	Yearling Weight, kg.	Carcass weight of Young/year in relation to live weight of mother, %
1. Herbivores				
Cattle	500	0.9	350	35
Camel	600	0.5	-	18
Sheep	60	1.0	50	42
Sheep	60	1.5	50	63
Goat	45	1.5	35	53
Capybara	45	7	25	194
Rabbit (extensive)	4	8	3	390
Rabbit (intensive)	4	48	4	2,900
Guinea pig	0.8	20	0.6	825
2. Omnivores				
Pigs	200	20	150	1,200
Chicken	3	100	3	9,000

Source: Schlolaut and Lange, 1983

b) The energy expenditure per kilogram of weight gain lies markedly below that of sheep (39%) and even 47% below that of cattle (Cock, 1977). The protein formation between the 6th and 16th weeks of life is 45% higher than in lambs (Sharkey, 1973). The advantageous utilization of energy and protein and the high reproductive rate, result in the highest productivity per area of small meat producing farm animal species (Spedding, 1975).

c) Utilization of kitchen and garden refuse, weeds, leaves

etc. make meat and wool production in small enterprises possible, independent of available farm land.

d) Adult weight is achieved in a 30% shorter time than in other meat production mammals (Taylor, 1980). This, combined with the short gestation period, makes possible a minimal generation interval of 150 days. This being the lowest for all meat-producing mammals. Combined with multiple births, it allows for a rapid adaptation of the animal stock to seasonal differences in feed availability and market demands.

e) In some African countries, rabbit meat commands a higher price than other types of meat. This is because it is considered as game or "bush meat". With the exception of Israel, no religious barriers are known to the consumption of rabbit meat. In some countries however, prejudices do exist because of a mistakenly assumed relationship to rodents. Where the religion considers white animals to be holy, prejudices exist against white breeds.

f) There are usually no problem in preserving (freezing, smoking) as in large animals. This is because the carcass can be cut into dish portions. The rabbit has therefore served as a source of fresh meat in Europe, both in ancient and recent times.

g) Rabbit meat is easily digestible. Only a slight amount of uric acid (the cause of gout) is formed through metabolization. Therefore, it is suitable for a special health diet.

h) The rabbit is very adaptable to different feeding and holding conditions. It is also practical for closely settled areas - it makes no noise that could bother neighbours (as does the chicken), and in addition produces relatively little odour.

i) The rabbit is one of the smallest meat animal, producing protein from roughage. It does not compete for food with man.

j) The rabbit is also suitable as a training object for other forms of animal production.

k) In many countries, the market values of the meat and wool are relatively high in comparison to other domestic animal products. The high productivity within a small space and the possibility of utilizing a wide variety of feed sources, allows for low cost rabbit production. In rural areas, rabbit production provides an income usually above that of other alternative.

These advantages make the rabbit an important livestock species for bridging the animal protein supply - demand gap, in areas where land space, initial capital investments and feed requirements for other livestock species are becoming a constraint.

2.2 AGRO-INDUSTRIAL BY-PRODUCTS FROM THE BREWERY INDUSTRY.

Beer consumption has increased dramatically in tropical countries over the last two decades and the number of breweries has multiplied considerably, particularly in Africa.

The Nigerian brewing industry which started with the establishment of a brewery in 1949, currently comprises of about 33 brewing plants.

According to Olomu (1984) an industrial by-product is defined as that material which remains after the main product of interest has been removed or extracted in an industry. The main grain by-product of interest in the brewery industry in Nigeria is brewers' spent grains or sorghum beer residue form the local alcohol brewing industries (Dogari, 1985). These grain by-products are usually low cost, low energy materials which can be used to formulate cheap rations for livestock feeding (Olomu, 1984). Bello (1984) further enumerated a number of benefits which may be derived from utilizing these agro-industrial by-products. These include:

a. Reduced dependance on imported feed ingredients which constitute a drain in foreign exchange.
b. Reduction in environmental pollution thereby improving environmental sanitation.
c. Provision of good sources of calcium, phosphorus, protein, B-complex vitamins and some essential amino acids which would have been wasted.

d. Creation of new employment opportunities at place of production and in secondary industries based on such raw materials.

Needless to say, the conversion of these by-products in the diets of livestock reduces the use of feedstuffs which have competitive usage with man e.g. maize.

2.2.1 The brewing process.

The brewing process involves the use of barley or other cereals which are treated so that starch under the influence of added diastase, is converted into malt-sugar during accelerated germination. The germination is interrupted by heating and the shrivelled roots (sprouts) are separated from the malted grains which are washed with water. The mixture is then filtered to yield wort as the filtrate, and brewers' spent grains as the residue. The wort is further processed for beer while the grains are considered "waste" (Sedam, 1957). Brewers' spent grain is the main by-product from the brewing industry. This spent grain when dried is referred to as brewers' dried grain (BDG) and is available for livestock feeding.

2.2.2 Description of some brewery by-products.

Brandis (1985) identified the following as brewery by-products or wastes: malt mash (this contained 85% water, 0.5% crude ash, 3.98% crude protein, 2.11% crude fibre and 2.86% crude fat), brewers' yeast, spent grain, malt sprouts, protein residues, culms, grain polishings and, hop mash.

According to Serres (1992), brewers' grain is the major by-product from brewing. Brewers' grain is the insoluble residue following malt extraction during mashing and it contains starch, sugars, crude fibre, crude protein and minerals. In the fresh state it contains up to 85% water, but dries easily. It has a protein content of about 20% but levels of crude fibre are often high (15%). It is for this reason that brewers' grain is limited in monogastric feeding to about a third of the final diet (Serres, 1992). A moisture level of below 15% is desirable for proper conservation. In the wet state, the product is usually referred to as "brewers' wet grain".

According to Bello (1984), the main by-products of the brewing and allied malting industries are brewers' dried grains, brewers' dried yeast, malt sprouts and dried spent hops.

Brewers' dried grains are defined as the dried, extracted residue of barley malt, alone or in mixture with other cereal resulting from the manufacture of wort. Brewers' dried grains is very fibrous and is a rich source of

fermentation products particularly B-vitamins (Babatunde *et al.*, 1975). Brewers' grains and other brewing by-products may be used for livestock feed in the wet (Crickenberger and Johnson, 1982), ensiled (Cebrian and Swan, 1979) or dried state (Babatunde *et al.*, 1975). Dried brewers' grains and dried brewers' yeast are the main by-products of brewing industry in Nigeria available for use in livestock feeding (Bello, 1984). It is regarded as an intermediate source of protein and energy (Alhassan, 1985). Most breweries however, do not make these by-product available in the dried form but rather contract out the disposal of the wet product to farmers or agent who dry them for sale. This has greatly limited its use for livestock feeding. Wet brewers' grains are reported to have an exposed storage life of about 4-5 days in warm or hot environment, and up to 8-days in cold weather (Mowat, 1980). Studies show that wet brewers' grains could be preserved in the wet state for future use without adverse effects. Myers and Ollier (1962) demonstrated that 5kg of salt per tonne of spent grain in wooden silos lined with polythene gave a silage, 20 weeks later of equivalent nutritional quality as the fresh material. Allen *et al.* (1975) effectively preserved brewers grains in open piles for 2-3 weeks by treating with 4% of a mixture of propionic acid and formic acid (85%). Lilly *et al.* (1980) have shown through laboratory and pilot scale studies that wet brewer's grains could be stabilized by incorporating 30% beet molasses

and 0.3% potassium sorbate stored in closed containers. Sunde *et al.* (1978) had earlier recommended the used of sorbic acid as a preservative. Bello (1984) reported the chemical composition of dried brewers' grains as 18-20% CP, 6% oil, 20% fibre, 0.05% total phosphorus, 0.20% calcium, 0.90% lysine, 0.40% methionine and 1960 metabolisabe energy (M.E.) kcal/kg.

Brewers' yeast contains a high level of protein with a full complement of amino acids, vitamins of the B complex and unidentified but important growth factors (Babatunde, 1986). The yeast may contain hop constituents which gives it a bitter taste and may render the beef unpalatable when included in large quatities. The composition of yeast varies with strains and conditions of growth.

Most, but not all breweries are able to separate out yeast for subsequent drying. The resultant yeast is brown with a characteristic smell. In spite of its bitterness, it is extremely palatable to livestock such as pigs (Serres, 1992). This product is high in protein (45% CP) and digestible carbohydrate and therefore is a sought-after commodity. It is also rich in B-vitamins as well having a good balance of amino acid which approaches that of animal proteins. This allows it to be used in diets of lactating and pregnant sows to a level of 2-3% (Serres, 1992). The only limiting factor in its use as identified by the author is its high price.

Table 2. Composition and energy values oft brewers' grains from various sources.

	BDG[1]	BDG[2]	SBR	BSR	Sorghum	Maize
DM	92.40	96.30	91.00	NA	89.00	87.00
CP	27.60	25.00	22.00	28.64	11.10	8.10
CF	19.60	11.40	8.40	12.42	2.00	8.00
EE	6.10	1.80	4.60	6.50	3.00	3.20
Ash	2.90	NA	8.61	7.27	1.80	1.60
NFE	43.80	52.60	47.39	45.17	71.10	66.10
Ca	0.36	NA	0.13	0.31	0.04	0.40
P	0.62	NA	0.16	0.56	0.31	0.27
kcal/kg GE	4996	-	NA	NA	NA	NA
DE, MJ/kg	1978	2870	NA	NA	NA	NA

BDG[1] - Brewers' dried grain (Babatunde *et al.*, 1975)
BDG[2] - Brewers dried grain (Maertens *et al.*, 1990).
SBR - Sorghum beer residue (Dogari, 1985).
BSR - Maize/sorgum based brewers grain (Udedibie & Emenalom, 1993).
NA - Not available

2.3. NUTRIENT CONTENT OF BREWERS' DRIED GRAINS.

One way of assessing the nutritive value of a feedstuff is by determining its chemical composition in terms of dry matter, energy, protein, fibre, vitamins and minerals. Brewers' dried grains (BDG) are reported to contain about twice the nutrient contents of the original grains except for the starch that was converted to alcohol (Kiessel and Prentiss, 1979; Mowat, 1980). Jensen *et al.* (1976) noted that as a result of the utilisation of the starch in the original grains for alcohol, low metabolisable energy values were associated with the use of the spent grains in monogastric diets. The nutrient composition of brewers' grain varies with place, type and source of grain, method of brewing

(Mclean, 1960) and even method of drying (Lopez and Carmona, 1981). This makes general statements on the composition of brewers' grains difficult.

Protein content.

According to Bello (1984), brewers' grains are intermediate in protein content ranking above rice bran. Reports from literature indicate that the crude protein level of conventional barley based brewers' dried grain (BDG) varies from 18-27% (Babatunde *et al.*, 1975; Lopez and Carmona (1981); Bello, 1984; Lufadeju *et al.* 1988; Alawa *et al.*, 1988; Maertens *et al.*, 1990). The protein content of sorghum beer residue is however given as 22% (Dogari, 1985) and a slightly higher value of 28.6% has been reported for maize/sorghum based dried grains by Udedibie and Emenalom (1993). According to Adegbola *et al.* (1988), the protein of BDG is highly insoluble and resistant to ruminal degradation.

Information on the amino acid content of brewers' dried grains is scanty. Perry (1980) and Pond and Maner (1974) reported that although the protein content of brewers' grain was high (20-30%), it does not contain a good balance of amino acids. However, according to Almquist (1972), BDG has adequate amount of essential amino acids, especially those that are deemed to be limiting in monogastric diets such as methionine 0.4%, phenyalamine 1.2%, threonine 1.0%, lysine 0.9%, tryptophan 0.4 and valine 0.6%. Ademosun (1973) also showed the amino acid content of BDG to be superior to maize

or guinea corn, which are used as the major energy sources in poultry rations in Nigeria.

Energy content.

Brewers' dried grains have been described by Babatunde *et al.* (1975) as very fibrous and may serve as an energy source. It is documented that the energy content of brewers' dried grain ranges from 1800-2500 kcal/ME/kg (Harms et al., 1969; Jensen, et al., 1976; Sullivan et al., 1978; Bello *et al.*, 1984). *Maertens et al.* (1989) reported the digestible energy (DE) value of BDG in rabbits as 2870kcal/kg. Jensen *et al.* (1976) noted that as a result of the conversion of utilization of the starch in the original cereal grains, low metabolisable energy values are to be associated with the use of BDG in monogastric animals.

Crude fibre content.

The crude fibre content of brewers' dried grains range from 11.7-21.5% (Babatunde *et al.*, 1975; Lopez and Carmona, 1981; Bello, 1984; Alawa *et al.*, 1988; Udedibie and Emenalom, 1993). Babatunde *et al.* (1975) noted that BDG being very fibrous is best siuted for ruminant feeding with very limited use in monogastric rations. However, Dogari (1985) reported a lower crude fibre value of 8.4% for sorghum beer residue. The maize/sorghum based brewers' grain has been described as less fibrous and more nutritious than the conventional barley based by-product.

Ash content.

Ash content ranging from 3.1 to 4.6% have been reported for brewers' dried grain by various authors (Babatunde *et al.*, 1975; Lopez and Carmona, 1981; Bello, 1984; Lufadeju *et al.*, 1986; Alawa *et al.*, 1988. Udedibie and Emenalom (1993) however reported a higher ash value of 7.27% for maize/sorghum based BDG.

The nutrient composition of BDG has made it a potential feed source for most livestock rations.

2.4. UTILIZATION OF BREWERS' DRIED GRAINS IN NON-RUMINANT DIETS.

Brewers' dried grains have been used in the diets of pigs (Babatunde *et al.*, 1975), beef cattle (Adeyanju and Ilori, 1976; Umunna *et al.*, 1982) and sheep and goats (Adebowale and Ademosun, 1981). Few works have been reported in rabbits (Omole and Ajayi, 1976; Alawa *et al.*, 1990).

2.4.1 Utilisation of brewers' dried grains in swine diets.

According to Serres (1992), the high fibre content (15%), low protein and great variability of brewers' grain limits its value for pigs. However, it is quite widely used in small-scale systems of pig production in Nigeria.

Babatunde *et al.* (1975) reported that when 70 weaner pigs were fed graded levels of 5, 10, and 15% BDG no significant

differences in average daily gains and efficiency of feed utilization was observed, but the average daily feed and digestible energy intakes were significantly affected. The authors concluded that inclusion of barley brewers' dried grains at 15% of the diet for growing pigs did not depress growth rate although nutrient digestibility was lowered. This level of inclusion substancially reduced total feed costs.

In another study, Yaakugh *et al.*(1988) replaced 25, 50 and 75% of the maize portion of rations fed to young pigs with brewers' dried grains. Their results showed that beyond 25% maize replacement, performance in terms of average daily gain and feed utilization was depressed.

Tegbe (1985) reported a significant decrease in the daily feed intake and daily gain when weaner pigs received up to 30% BDG levels in their diets in the starter phase. During the grower and finisher phases they however reported a significant increase in feed intake, daily weight gain and poorer feed to gain ratio. They concluded that young pigs (starters and growers) could tolerate 10% BDG in their diets while other pigs (finishers) can be fed as much as 20% BDG in their diets without any detrimental effect on performance.

Madubuike (1988) fed graded levels of BDG up to 15% level in the diets of early weaned pigs and reported no adverse effect on total gains and average weight gains of the pigs. In addition, average daily feed intake and feed to gain ratio increased with increasing levels of BDG in the diets. The

pigs placed on the 15% BDG however consumed more feed per unit gain and also scoured more frequently than the others. This showed a lower degree of tolerance for increased fibre level. They reported that the 15% BDG which has a higher fibre level may have also depressed digestion and the pigs made up their gain through increased feed intake, which may have become responsible for the observed scouring.

Quemere et al. (1983) fed BDG to 168 pigs at 0 (control), 10, or 20% and reported similar daily feed intake for all the diets. Energy intake when compared with the control was 3% less or 8% less with 10 and 20% BDG respectively. The rate of gain was 18% less with 20% BDG. For females, rate of gain was not affected with 10% BDG but was 7% less with 20% BDG. They also reported a non-linear increase in the feed intake/kg gain with increasing dietary BDG during the growing period. This trend was less marked during the finishing period. Dietary BDG reduced the carcass yield, especially for females given 20% BDG. Carcass grading index was reduced by BDG parallel to the decrease in carcass muscle percentage.

Wahlstrom and Libal (1976) fed pregnant sows on diets containing 0, 20 and 40% BDG and reported no significant treatment effect on litter size, litter and individual pig weight at birth and weaning. Gestation weight gains were however significantly different for sows on the different BDG levels, with sows on the 20% BDG recording the highest gain

while the 40% diet gave the lowest.

2.4.2 Utilisation of brewers' dried grains in poultry diets.

The use of brewers' dried grains (BDG) in poultry diets has been well documented. It has been found that BDG can be incorporated into poultry starter and grower mash rations at levels of up to 10% and 15% respectively without adverse effects on the performance of the birds (Ademosun, 1974; Jensen, 1981; Ibrahim, 1986).

Broiler diets.

From trials conducted with broilers, Olomu (1984) reported that with the addition of siutable fats, broiler starters may be able to tolerate up to 30% BDG and broiler finishers up to 37% BDG without much adverse effects.

Onwudike (1983) reported that feeding diets containing 30% BDG did not affect weight and carcass yields of broiler chickens given diets with up to 30% BDG from 21 days to 11 weeks old. Chickens given large amounts of BDG showed a significant increase in size of pancreas and a decrease in abdominal fat and size of liver. The most efficient diet in terms of amount of feed to produce 1kg of gain, was that with 15% BDG.

Deltoro Lopez and Fernandez (1981) gave diets with up to 40% *BDG to broiler chickens from 0 to 12 weeks of age, and* found no treatment effect on feed intake or dressing

percentage. Digestive tract weight significantly reduced when using 20% or more BDG. Abdominal fat pad significantly decreased in weight with the use of BDG. They concluded that BDG should not exceed 10% for birds of 0-8 weeks old or 20% for birds of 8-12 weeks old.

Layer diets.

Ademosun (1973) employed diets containing up to 30% BDG for chicks from 0-8 weeks of age. No differences in food consumption were found, but for body weight gain and feed efficiency it appeared that BDG should not exceed 10%. In a second trial, the author fed diets containing up to 45% BDG to growing birds from 8-18 weeks. The results showed that 30% BDG caused an increase in food intake and a deterioration in feed efficiency.

Onwudike (1981) found that hen-day egg production value was highest for birds on 30% BDG. The average egg weight was also highest for birds at 20% level of BDG and mean daily feed intake was highest at 40%. This was expected because as the energy content of the feed falls, there is a tendency for increased feed consumption.

For 8 months , Harco hens which had been laying for about 10 weeks were given one of 5 diets containing 0, 10, 20, 30 or 40% BDG (Onwudike, 1987). Average hen-day production values on the above diets were 56.7, 56.5, 58.7, 60.9 and 55.8% respectively; average egg weight was 59.3, 59.7, 60.9, 62.4 and 62.3g and mean daily feed intake was 121.6, 130.8, 154.2,

166.4 and 168.9g.

Deltoro-Lopez *et al.* (1981) in a different trial, fed diets containing 0, 15, 30, 45 or 60% BDG to 20 Rhode Island Red laying hens in the seventh month of lay. The experiment lasted 75 days after which 90% BDG was offered to the same hens for two weeks. Diets containing 45% or more BDG had significant difference in digestibility of nitrogen or nitrogen retention. Feed intake, egg production, feed efficiency, egg weight, egg quality and body weight gain were also studied. Diets with 15 or 30% BDG seemed to be adequate, although the losses of body weight and shell quality suggested that this level should not be used without further research. At 60% dietary level, BDG caused a significant decrease in most of the characteristics studied. The use of 90% BDG caused a reduction in feed intake, large body weight losses and, in the second week of the experimental period, an inhibition of the lay.

Deltoro Lopez *et al.* (1982) fed BDG to laying hens at the levels of 0, 4, 8, 12 and 16% of the diet. Feed intake, egg production, feed conversion efficiency and body weight were not significantly different among the groups but egg weight, interior egg quality and fat content of liver were significantly greater with 16% BDG than in control group.

Deltoro Lopez *et al.* (1983) found that feed intake, egg production, feed conversion efficiency and body weight were not significantly different among groups when BDG was fed to

Rhode Island Red hens at 0, 4, 8, 12 or 16% as replacements for some of the sorghum, barley, soya and lucerne of the diet. However, egg weight, interior egg quality, and fat content of the liver were significantly greater with 16% BDG than in the control group.

2.4.3 Utilisation of brewers' dried grains by rabbits.

Although studies have been conducted on the use of brewers' dried grains as a feed supplement for the various classes of livestock listed above, information on its utilization by rabbits is limiting as its use in rabbit feeding is very recent. Alawa *et al.* (1990), described the performance of growing rabbits fed diets based on corn in which various proportions of the corn were replaced with BDG. They reported that the rabbits tended to consume more dry matter as the level of BDG in the diets increased. This was associated with increasing dietary fibre concentrations caused by increasing proportion of BDG in the diet. Least final weights and gains were also recorded for this group of rabbits which also had the poorest feed conversion ratio. A depression in growth rates and increase in the amount of feed consumed per unit of live weight gain was noticed as BDG in the diet increased. The apparent digestibilities of the diets were significantly depressed ($P<0.05$) by the inclusion of BDG. They concluded that the replacement of 25-50% of the cereal grain portion of diets did not cause serious loss in

performance, measured as liveweight gain, although 25% inclusion level was considered best, being comparable to the control.

In metabolism trials, 8 Spanish giant rabbits were given BDG containing 28.85% CP mixed with 50% dried bean pods or supplemented with mineral and vitamin premix 3% and sugarbeet molasses 30%. Digestibility of nutrients in the grains, except for CP and EE, ascertained by difference, was increased by adding bean pods. Palatability of brewers' grains was improved by both treatments (Fonolla, *et al.*, 1985).

Omole and Ajayi (1976) showed that the incorporation of BDG in rabbit rations up to 15% led to an increase in daily weight gain, but further increase in BDG concentration up to 45% resulted in reduced body weight gain and efficiency of feed utilization. In another study by Alawa and Amadi (1991), it was reported that BDG had a greater potential for utilization compared to corn cobs or wheat bran in diets in which 35% of these by-products were used to replace maize.

2.4.4 Utilisation of sorghum beer residue or BKT waste.

The production of the local beer known as "burukutu" (BKT) using sorghum or maize, generates spent grains which is of variable quality depending on the system used. This by-product has also been referred to as "sorghum beer residue" (Dogari, 1985). Though it has been fed to livestock, literature is still very scanty on its utilization. The grain

source is mostly sorghum and is used by pig farmers singly or in combination with other feedstuffs in pig fattening schemes (Tegbe *et al.*, 1995).

In a feeding trial, Tegbe *et al* (1995) fed weaner pigs graded levels of 0, 10, 20 or 30% local spent grain (BKT waste) and found a decrease in weight gain, feed intake. Feed to gain ratio and feed cost per kilogramme gain, as the level of BKT waste increased in the diet. The 10% BKT diet gave the best result. In another trial, these authors fed diets of 0, 12.5, 25 or 37.5% BKT waste to adult pigs and found that performance characteristics in terms of feed intake, weight gain and feed:gain ratio were not affected by the level of BKT waste fed.

According to Dogari (1985), sorghum beer residue or BKT waste, can be included up to 50% of broiler starter diets. From this result there were no significant differences in weight gain of broilers fed sorghum beer residue and those fed maize as the main energy source. However because of the low energy level of sorghum beer residue, inclusion levels higher than 50% led to significantly lower weight gains even though this led to a saving in cost of feed. Dogari (1985) also reported that increasing levels of sorghum beer residue in the diets of broiler chickens up to 50% depressed weight gains, feed efficiency and feed cost per kilogramme gain. Feed consumption increased and mortality was unaffected.

Dogari (1985) gave its chemical composition as shown below. Alongside these values is the composition of brewers dried grain.

Table 3: Chemical, tannin composition and amino acid profile of sorghum beer residue.

	Sorghum beer residue	Brewers' dried grains
DM, %	91.00	97.95
CP, %	22.01	19.95
EE, %	4.60	7.10
CF, %	8.40	18.63
Ash, %	8.61	3.15
Ca, %	0.13	-
P, %	0.16	-
Tannin, %	3.40	-
Lysine g/16gN	0.54	0.83
Histidine ,,	0.63	0.58
Arginine ,,	0.83	0.95
Aspartic acid ,,	1.52	-
Threonine ,,	0.92	0.70
Serine ,,	1.13	-
Glutamic acid ,,	3.75	-
Proline ,,	2.29	-
Glycine ,,	0.77	0.82
Alanine ,,	1.90	-
Cystine ,,	0.49	0.98
Valine ,,	1.27	0.01
Methionine ,,	0.34	0.29
Isoleucine ,,	1.09	0.77
Leucine ,,	2.65	1.60
Tyrosine ,,	1.11	-
Phenylanine ,,	1.46	1.16
M.E., kcal/kg	1764	1960

Source: Dogari, 1985.

2.5 PROBLEMS ASSOCIATED WITH FEEDING BREWERS' SPENT GRAINS.

Most literature reports evaluate the utilization of brewers' grain with respect to its fibre component. Pond and Maner (1974) reported that the main problem with the use of brewers' grain in monogastric diets lies in the fact that it is a low energy, high fibre (bulky) feed. They suggest that it is best suited for ruminants that can handle high fibre, low energy feed better than the monogastrics. Brewers' grain have been reported to contain high levels of selenium and levels of over 0.045 ppm may limit performance in feedlot cattle especially if dietary protein is low or deficient (Maclean, 1960; Crickenberger and Johnson, 1982). Convard and Moxon (1979) reported that about 19% of the selenium supplied in dried brewers' grain to dairy cows appeared in milk. This was especially so where the dried grains were the main source of dietary selenium. They sounded a note of caution as to the human health hazards of selenium toxicity from milk.

However, the inclusion of brewers' grain in diets is said to reduce the incidence of parakeratosis in the rumen of animals fed cereal grains. The animals also showed less indications of liver abscesses (Oster *et al.*, 1977; Preston *et al.*, 1973).

The existence of a large number of fungi in fresh brewers' grains kept in the open have been documented, though

the grain did not lose colour or odour (Lopes and Pascal, 1981). Sunde *et al.*, (1979) had earlier observed that no pathological mould had been associated with the use of wet brewers' grain.

Tangle et al. (1960) reported that long term feeding of brewers' grain to dairy cows often produced infertility. They related this to the imbalance of the essential amino acids, especially tryptophan which they observed to be very low 0.1g/100g protein). They recommended the use of about 10kg brewers' grain per day alongside typtophan-rich-feeds in order to check the problem. However, Crickenberger and Johnson, (1982) observed in heifers that feeding increased quantities of wet brewers' grain, increased selenium intake levels without apparent beneficial or detrimental effect on reproductive performance.

2.6 INDUSTRIAL UTILIZATION OF SORGHUM IN NIGERIA.

Until recently, sorghum has been a principal staple food in Nigeria. The Structural Adjustment Programme (SAP), made it imperative however for food, beverage and brewery industries to explore options of finding local sources of their raw materials (Aribisala, 1989). This has become an important factor in enhancing the utilization of sorghum. The emerging principal uses of sorghum as an industrial raw material includes production of biscuits and confectionery, beverages, weaning foods and beer. Currently, sorghum has

been identified to have the greatest potential of being used as a material in the brewing subsector. Many brands of beer in the market now have substantial content of local sorghum and maize (Aribisala, 1989).

In the utilization of sorghum to produce beer and flour, some by-products are naturally made available for commercial feed manufacture (Aduku, 1989). These include:

Brewers' sorghum residue: This is obtained when sorghum malt has been used for beer production. This is currently in mixtures with maize grits and is used in feed formulation arbitrarily since the chemical composition is not known.

Sorghum floats: These are light, immature or weevil attacked grains which float on water in the process of soaking grains in a malting process.

Sorghum bran: The bran is derived from the milling of sorghum into flour.

Sorghum sprouts: These are shoots of germinated grains in the production of malted sorgum used in beer production. The germinated grains are dried and the shoots broken off. These shoots are high in protein and amino acids, high in cyanide (Ikediobi *et al.*, 1987) but low in tannin (Kubiczek *et al.*, 1984).

2.7 TANNIN IN SORGHUM AND SORGHUM PRODUCTS

Sorghum grains contain an antinutritive factor called tannin. Due to the presence of tannin, the feeding value of

sorghum is between 85-95% of that of maize. Tannin have been found to have a deleterious effect on the nutritive value of sorghum (Vohra *et al.* 1966) which may affect its feeding value for monogastrics. It has been shown that protein in high tannin sorghum has lower nutritive value than that of low tannin sorghum due largely to the harmful effects of tannin exerted in the digestibility of proteins (Bagepalli *et al.*, 1980). Nelson *et al.* (1975) showed that there is a reduction in amino acid availability with increasing tannin content. Sorghum grains of high tannin content are of importance to agronomists who prefer these high tannin varieties for their resistance to bird attack, inhibition of pre-harvest germination and resistance to mould growth (Harris and Burns, 1970).

Okoh *et al.* (1989) reported a great deal of variation in the tannin content of various sorghum grain varieties, ranging from 0.012% in HP8 to 0.215 % in YG5760. They observed that about 11 varieties of those studied had 0.11-0.215% tannin content.

Considerable decreases in growth rate and feed efficiency of rats and chicks due to presence of dietary tannin in appreciable amounts were reported by Featherstone and Rogler (1975). Ward *et al.* (1977) reported a reduction in feed intake, feed gain ratios, dry matter and amino acid negative weight gains when a diet containing 3.9% purified condensed tannin was fed compared with the control which had no added

tannin. Connor *et al.* (1969) also reported a depression in testis weight and total lipid content and an individual bird variation in liver weights. These authors concluded that apart from the depression in feed intake, tannin exerts other toxic effects which have to be further investigated. However, Potter *et al.* (1966) showed that tannic acid levels of up to 2% cause egg yolk mottling.

2.8 CRUDE FIBRE DIGESTION AND UTILIZATION IN RABBITS.

Rabbits are typically herbivorous animals which consume high forage diets. Though they feed on large quantities of fibrous feedstuffs, they are not efficient in utilizing dietary fibre (Cheeke *et al.*, 1986). Rabbits being hindgut fermenters, selectively retain large particles in the caecum. Normal peristaltic movements propel the larger, less dense fibre particles through the colon and at the same time contractions of the colon moves fluids and small particles which are high in density, in a retrograde manner to the caecum. The small particles and fluids are retained for prolonged periods in the caecum (Pickard and Stevens, 1972), allowing for extensive fermentation. In essence, the digestive strategy is to separate fibre and non-fibre components in the hindgut, with the rapid excretion of the non-fibre constituents for fermentation in the caecum. The non-fibre components are digested efficiently, because they are re-ingested as the cecotropes and thus subjected to more

than one passage through the digestive tract. Fibre on the other hand is very poorly digested in the rabbit, because it is rapidly propelled through the colon and excreted in the hard feces.

In spite of its poor digestion, fibre plays an important role in maintaining normal functioning of the digestive tract and in preventing enteritis.

2.8.1 Digestibility of crude fibre in rabbits.

The digestibilities of all components of a diet decrease as the fibre level increases and they vary with the type of feedstuff. Feeds high in cellulose and lignin generally have a crude fibre digestibility of less than 15% in rabbits while non-lignified materials such as beet pulp have crude fibre digestibility as high as 60% (Maertens and De groote, 1984). Cheeke and Raharjo (1988) reported that the digestibility of fibre of grain milling by-products such as rice bran is high. The increase in digestibility of cereal straw and sawdust through alkali treatment was reported by De Blas *et al.* (1979) and Omole and Onwudike (1981). The effect of alkali is probably due to the reduction of the lignin content, and possibly increased degradation to small particle sizes by mastication, resulting in increased cecal retention of the fibre fraction (Cheeke *et al.*, 1986). Grinding of feeds to reduce their particle size results in an increased cecal retention time (Laplace and Lebas, 1977).

UNIVERSITY

2.8.2 The role of fibre in rabbit nutrition.

Diets low in fibre have been found to reduce growth rates of weanling rabbits (Champe and Maurice, 1983; Cheeke and Patton, 1978; Lebas and Laplace, 1977). Pote *et al.*, (1980) showed that there was an increase in average daily gain, daily intake and daily DE intake when a fibre source such as alfalfa meal was added to a cereal based diet. There are several possible explanations for the low growth rate of rabbits fed a high energy, low fibre diet. Laplace and Lebas (1977) observed that finely ground feed increased the retention time of digesta in the cecum, and decreased dry matter intake. Lebas and Laplace (1977) further reported that highly digestible diets are consumed in lower quantities and retained in the digestive tract longer than high fibre diets. Increasing the retention time of feed in the digestive tract is a precursory sign of diarrhea, which is preceded by cecal-colonic hypomotility (Laplace, 1978). This author concluded that attempts to improve efficiency of feed utilization by lengthening retention time and increasing recycling by cecotrophy are generally unsuccessful; any disturbance of the normal rhythms of feed intake and fecal excretion pattern is generally deleterious. Thus according to Cheeke *et al.* (1986), a plausible explanation for reduced growth rate of rabbits fed low fibre diets is that prolonged cecal retention time occurs, with reduced feed (and energy)

intake and a predisposition to diarrhea. He noted that the favorable effects of fibre, termed a "ballast" effect by Collin *et al.* (1976), are apparently due to a stimulation of cecal-colonic motility, probably by the scabrous effects of the larger particles and the increased bulk of the digesta. This is analagous to the roughage effect of forages in ruminant gut motility. The minimum levels of dietary fibre which have stimulated maximum growth rate in various studies ranged from 9 - 11 % crude fibre (Champe and Maurice, 1983; Cheeke and Patton, 1978; Collin *et al.*, 1976; Pote *et al.*, 1980; Spreadbury and Davidson, 1978).

Numerous investigators (Collin *et al.*, 1976; Laplace, 1978; Pote *et al.*, 1980 and Spreadbury and Davidson, 1978) have noted that dietary fibre has a protective effect against diarrhea in weanling rabbits. The exact mode of action is not clear. Cheeke and Patton (1980) proposed that low fibre and high starch diets promote carbohydrate overload of the hindgut, leading to the proliferation of pathogens. Borriello and Carman (1983) attributed enterotoxemia (a major form of enteritis) to toxins produced by *Clostridium spiroforme*. The diarrhea-promoting effects of low fibre diets are therefore associated with two factors: (1) the low fibre level results in a reduction in cecal-colonic motility, so that increased cecal retention time of ingesta occurs, and (2) a low fibre diet is a priori one high in readily available carbohydrate (Cheeke *et al.*, 1986).

Another beneficial effect of fibre is that they prevent cases of trichobezoars and hair pulling. Masses of hair balls (trichobezoars) in the stomach block the pyloric opening and ultimately results in death from starvation. In pregnant does, hair balls lead to ketosis and fatty acid syndrome (Patton *et al.*, 1983). Rabbits eat hair when fed low fibre diets in an attempt to satisfy a craving for fibre.

CHAPTER THREE

3.0 EFFECT OF GRADED LEVELS OF BREWERS' SORGHUM RESIDUE ON PERFOMANCE OF WEANER RABBITS.

3.1 ABSTRACT

Proximate composition of brewers' sorghum residue (BSR) was determined and a six week feeding trial was conducted to evaluate the feeding value of BSR for weaner rabbits. In this experiment, five diets were formulated to contain 0, 10, 20, 30 and 40% levels of BSR respectively. Each diet was fed to three replicates of four weaner rabbits with an average initial weight of 617g. Carcass analysis and nutrient digestibility determination were conducted at the end of the feeding trial.

Brewers' sorghum residue contained 93.72% DM, 30.16% CP, 11.82% EE, 12.93% CF, 2.51% ash, 0.14% Ca, 0.43% P. The soluble tannin and gross energy content were 6.02% and 4.92kcal/g respectively.

The results obtained from the growth study with weaner rabbits showed significant ($P<0.05$) effects of treatments on daily weight gain, daily feed intake, feed to gain ratio, feed cost per kilogram and feed cost per kilogram live weight gain. Weight gain was significantly higher ($P<0.05$) at 20% BSR level when compared with the control but reduced significantly ($P<0.05$) at higher levels of BSR inclusion. Feed intake decreased significantly ($P<0.05$) as the level of BSR

increased in the diet. Feed to gain ratio also became significantly ($P<0.05$) poorer at higher levels of BSR begining from the 30% level of BSR inclusion. Increase in dietary level of BSR significantly ($P<0.05$) lowered feed cost/kg. Feed cost/kg live weight gain reduced significantly ($P<0.05$) up to 20% BSR level then increased thereafter. Mortality was not significantly ($P>0.05$) affected by dietary treatments.

Dressing percentage, gut plus caecum weight, gut length and abdominal fat content were significantly reduced ($P<0.05$) as dietary BSR level increased when compared with the control. There were however no significant ($P>0.05$) effects of treatment on liver and edible organ (liver, heart, kidney) weights.

The digestibilities of DM, CP, CF, EE and ash were not significantly ($P>0.05$) affected by increase in the levels of BSR in the diet.

The results of this experiment showed that weaner rabbits could tolerate up to 20% BSR inclusion in their diets without any detrimental effects on their performance.

3.2 INTRODUCTION

Due to the increasing cost of feed concentrates for livestock production, emphasis is now been placed on sourcing alternative feed ingredients, particularly those which do not have competitive usage with man. Such alternative feed sources include agro-industrial by-products such as brewers' spent grains from the brewing industry. Prior to the ban on the importation of barley malt in 1988, the main by-product from the brewing industry was brewers' spent grains. It was basically barley-based. This by-product has served as a major source of both energy and protein for livestock (Tegbe, 1985). It is also known to contain proportionally more valuable vitamins, fat, fibre and protein than were contained in the barley grain used (Kingsell *et al.*, 1979). Being a by-product of fermentation, it is believed to contain unidentified growth factors (Singh, 1988). The high crude fibre content of barley-based dried brewers' spent grains (over 20% CF), limits its use in the diets of monogastric animals, particularly poultry (Ademosun, 1973; Nelson, 1984). It has however been successfully used as feed for pigs (Babatunde *et al.*, 1988), sheep and goats (Adebowale and Ademosun, 1981; Adu, 1985) and rabbits (Omole and Ajayi, 1976; Alawa *et al.*, 1990).

The ban on the importation of this exotic cereal, led most breweries in the country into using sorghum or maize or a combination of both, for the production of lager beer

(Aribisala, 1989). This consequently resulted in the production of a sorghum-based or maize/sorghum-based brewers' residue which is termed here as "brewers' sorghum residue". Studies conducted by Udedidie and Emenalom (1993), showed that this by-product can be used up to 88% in the diets of broiler diets. These authors found it to be less fibrous and more nutritious than the conventional barley-based brewers' residue.

A close variant of brewers' sorghum residue termed "sorghum beer residue", is derived from the fermentation of sorghum for the production of the local beer called "burukutu" (Dogari, 1985). This by-product has been shown to contain a high percentage of protein (22%) and a low energy content (1764kcal/kg). Broiler chickens were able to tolerate this by-product up to 50% of their diets.

Brewers' sorghum residue is now widely used by most livestock producers in a harphazard manner since they have no adequate information on its composition. The chemical composition of this product varies with the grain source, propotions of the various grains used, brewing process (Kafidiya, 1992 personal communications). It has become necessary to determine the chemical composition of the by-product before incorporating it into the diets of rabbits since little or no information exists on the use of brewers' sorghum residue in livestock diets.

The experiments carried out were therefore designed to:

i. determine the proximate composition of brewers' sorghum residue
ii. determine the effect of dietary inclusion of brewers' sorghum residue on performance of weaner rabbits
iii. determine the effect of brewers' sorghum residue on overall feed cost.

3.3 MATERIALS AND METHODS.

3.3.1 Collection and processing of brewers' sorghum residue.

The brewers' sorghum residue (BSR) used for this study was obtained in the wet state from the Nigerian Breweries Plc., Kaduna, brewers of 'Star Lager beer'. Four tipper loads of the wet BSR were collected in four trips from the brewery. The wet BSR was then processed by spreading on cement floor and left to sun dry for three days with regular turning to prevent mouldiness.

3.3.2 Determination of the chemical composition of brewers' sorghum residue.

Representative samples of dried brewers' sorghum residue were collected and chemially analysed to determine their composition for dry matter, crude protein, crude fibre, ether extract, ash, calcium and phosphorus, according to AOAC (1975) methods. Nitrogen composition was determined using micro kjeldahl apparatus. Gross energy of the BSR was determined

with a Gallenkamp oxygen ballistic bomb calorimeter. Soluble tannin concentrations were determined at the ILCA (now ILRI) labouratory at Addis Ababa.

3.3.3 Experimental diets, animals and management

Five experimental diets were formulated to contain 0, 10, 20, 30 and 40% levels of BSR respectively. All the diets contained 18%CP with the metabolizable energy varying depending on the content of BSR in the diet. Rice offal, bone meal, vitamin-mineral premix and salt formed 15, 3.0, 0.25 and 0.50% of the diets respectively (Table 4).

Sixty (60) mixed breeds of rabbits weighing an average of 617g, were randomly assigned to the five dietary treatments with 12 rabbits per treatment. All experimental animals were housed in groups of four per replicate in cages of dimension 60x50x45cm. The animals were weighed at the beginning of the experiment and weekly thereafter. Feed consumption was recorded daily. Feed and water were provided *ad libitum*. The feeding trial lasted for 6 weeks. Parameters measured include average daily feed intake, average daily weight gain, feed to gain ratio, feed cost per kilogram and feed cost per liveweight kilogram gain. At the end of the feeding trial, one rabbit per replicate was slaughtered to determine the effect of dietary treatments on carcass parameters. Four rabbits were randomly selected from each treatment group at the end of the experiment and transferred to metabolic cages where total faecal collections were taken to determine the

apparent nutrient digestibilities of the diets. Polythene sheets were placed under each cage to collect the faeces daily for 7 days. These were then weighed pooled and stored in the freezer. At the end of the trial the faeces were oven dried at 70°C for 24 hours and grounded for chemical analyses. The digestion trial and calculation of the apparent nutrient digestibility coefficients are according to the procedure given by Harris (1983) see Appendix 30

3.3.4 Proximate analysis

Nutrient contents of feed and faeces were analysed according to the AOAC (1975) methods described in 3.3.2.

3.3.5 Statistical analysis

Data collected were subjected to analysis of variance and differences between treatment means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1980). The trends were determined using curvilinear contrasts.

3.4 RESULTS AND DISCUSSION.

3.4.1 Nutrient content of brewers' sorghum residue

The results of the chemical analyses of brewers' sorghum residue are presented in Table 5.

The crude protein value of 30.16% reported for brewers' sorghum residue (BSR) was higher than the values of 22.01% obtained by Dogari (1985) for sorghum beer residue. It was closer to the value of 27.6% and 28.64% reported for barley-based brewers'dried grain and maize/sorghum-based brewers'

dried grain reported by Babatunde *et al.* (1975) and Udedibie and Emenalom (1993) respectively. The high crude protein content obtained in this study confirms the reports of other workers who found that brewers' sorghum residue is very high in protein. This high protein content of BSR is as a result of the concentration of protein in the residue as the extraction of starch through fermentation occured.

The crude fibre value of BSR (12.93%) is in agreement with the value of 12.42% reported by Udedibie and Emenalom (1993). It is however higher than the value of 8.40% obtained for sorghum beer residue reported by Dogari (1985) but lower than the values of 18.83% and 21.5% reported for brewers' dried grains by Olomu (1988) and Alawa *et al.* (1988) respectively. The crude fibre results confirm that BSR is high in fibre which will likely have a detrimental effect on the performance of monogastric animals if fed at very high levels. The high crude fibre value of BSR observed in the present study is probably due to a high concentration of the fibrous testa in the resdue after the removal of starch.

The ether extract value of 11.82% obtained from this study was found to be higher than values of 6.5% reported for maize/sorghum based BDG by Udedibie and Emenalom (1993). The differences observed could be due to the variation in cereal grains used, the method and degree of accuracy of labouratory techiques used for analyses. When maize grit is used, the germ containing most of the fat is removed. Sorghum grain on

the other hand is used without removing the testa and germ containing fat. The process of fermentation reduces the carbohydrate component while the fat content is increased.

The ash (mineral) value of 2.51% obtained in this study were found to be close to the value of 2.9% and 3.15% reported by Babatunde *et al.* (1975) and Olomu (1988) for brewers' dried grains. It was however lower than the values of 8.61% and 7.27% lower than the values reported for sorghum beer residue and maize/sorghum based BDG by Dogari (1985) and Udedibie and Emenalom (1993) respectively. The calcium content of 0.14% is in agreement with the value of 0.13% reported by Dogari (1985) for sorghum beer residue but lower than the 0.31% reported by Udedibie and Emenalom (1993) for maize/sorghum based brewers' dried grain. The phosphorus value of 0.43% compares favourably with 0.56% reported by Udedibie and Emenalom (1993) but higher than 0.16% reported by Dogari (1985).

The dry matter value of 93.72% obtained in this study was within the range of 88.0-96.3% reported for barley-based BDG by other workers (Babatunde *et al.*, 1975; Bello *et al.*, 1984; Lufadeju *et al.*, 1986; Dogari, 1985; Alawa *et al.*, 1988). This differences in the dry matter value observed could be due to variations in the moiture content of the by-product before dry matter determination.

The gross energy content of 4.92Kcal/g agrees with the value of 4.28Kcal/g reported for maize/sorghum based dried brewers' grain by Udedibie and Emenalom (1993).

The tannin content was higher (6.02%) than that of sorghum beer residue (3.40%) by Dogari (1985). This difference may be due to the variety of sorghum used, the proportion of sorghum to other grains used for the beer production, the brewing pocess and the method of tannin extraction.

3.4.2 Performance of weaner rabbits fed brewers' sorghum residue

The performance of weaner rabbits fed graded levels of brewers' sorghum residue are presented in Table 6.

There was an inverse relationship between dietary level of inclusion of BSR and feed intake (Table 6). Feed consumption decreased linearly ($P<0.05$) as the level of BSR in the diets increased. Average daily feed intake for the control diet was highest (64.06g) while the lowest intake of feed was recorded for the 40% BSR diet (34.37g). Rabbits on the 40% BSR diet therefore consumed less of the feed when compared to those on the control diet. This result is in agreement with the findings of Udedibie and Emenalom (1993) who reported that birds on maize/sorghum based dried brewers' grain diets consumed significantly less feed when compared to those on the commercial (control) diet. Tegbe *et al.* (1985) observed a similar decrease in feed intake of weaner pigs fed diets containing up to 30% brewers' dried grain (BDG). Yakuugh *et al.* (1988) also reported that average daily feed

intake decreased linearly as level of BDG replacing maize increased in the diet. Alawa *et al.* (1990) however reported that dry matter intakes of rabbits increased though non-significantly with increase in dietary BDG. It is known that rabbits consume for energy. This implies that rabbits would consume more of a feed with low energy content. Therefore, it is expected that rabbits beyond 10% BSR dietary level would consume more feed as was reported in the study by Alawa *et al.* (1990). This was not the case in this study. A few plausible explanations could be advanced for this observation. Though young, fast growing rabbits adjust their voluntary food intake in response to changes in the energy density of their food, a number of factors can interfere with this auto-regulating ability. When the energy content of the ration falls below the recommended value, the young rabbit is unable to eat sufficient amounts of the feed to supply its energy needs and growth is thereby reduced (Lang, 1981). In the present study, caloric density of the diets decreased as the level of BSR inclusion increased in the diets, falling below the recommended value in treatment 4 and 5. This explains the low intake of feed for these treatment groups. Further explainations can be deduced from the reports of Fekete *et al.* (1985) who noted that antinutritive substances may affect the auto-regulating capacity of rabbits. In this study, one antinutritive factor identified was tannin which is present in the sorghum. The dietary content of tannin increased from

0.60-2.41% as BSR in the diets increased from 10-40% level of inclusion. The presence of tannin and the astrigent nature have been reported to reduce voluntary feed intake (Kumar and Singh, 1984). McLeod (1974) also reported that tannins tend to depress the nutritive value of fodder for ruminants by reducing its voluntary feed intake and digestibility.

Feed consumption was regressed against BSR levels and the following prediction equation was obtained:

$$Y = 74.599 - 7.399X$$

where Y = Feed intake (g/feed/rabbit/day)

X = Treatment level

The results show that inclusion of brewers' sorghum residue significantly ($P<0.05$) affected weight gain. A quadratic response ($P<0.05$) was observed for average daily weight gain of rabbits. Weight gain increased from 0 to 20% BSR inclusions and decreased thereafter. The weight gain of rabbits on 20% BSR diet was higher than the values for all other diets including the control. There were however, no significant difference ($P>0.05$) in weight gains of rabbits fed 10 and 20% BSR diets and the control. Diet 5, which contained 40% BSR, gave a significantly ($P<0.05$) lower weight gain than all other diets. These results compare favourably with those of Omole and Ajayi (1976), who reported improved gains only up to 15% for rabbits fed diets of 0 to 45% BDG diets. Alawa *et al.* (1990) reported a non significant decrease in daily weight gains when BDG replaced 25, 50 and 75% maize of the diets of

rabbits. The authors attributed this decline to increased dietary crude fibre concentration. Madubuike (1988) also reported that total gains of pigs did not differ when placed on up to 15% BDG diets. Depression in body weights was reported when BDG was included in pig diets beyond 20% level (Deltoro and Fernandez, 1982; Tegbe, 1983). However, Babatunde *et al*. (1975) also reported that pigs which received 10% BDG recorded the fastest growth than those on 5 or 15% BDG diets. The reduction in weight gain at higher levels of BSR inlusion in this study, could be attributed to the reduction in feed intake and reduced energy intake consequently reducing the quantity of available nutients at the tissue level. The level of dietary tannin in the diets also increased from 0.61 in the 10% BSR diet to 2.40% in the 40% BSR diet According to Dale *et al*. (1980), a significant depression in body weight gain occured when diets containing 0.5% and 1.0% tannic acid were fed to broilers in a basal broiler starter ration. Tannins also diminsh the permeability of the gut wall by reacting with the outer cellular layer of the gut, so that the passage of nutrients through the gut wall is reduced (Mitjavile *et al* ., 1977). In addition tannins react with protein to form protein-tannin complexes (Kumar and Singh, 1984), reduces amino acid availability (Nelson *et al*., 1975; Rostagno *et al*., 1973b) and also reduces the availability of sulfur (Garner and Hurwood, 1976).

The following prediction equation was obtained when

weight gain was regressed against the dietary levels of BSR:

$$Y = 11.143 + 5.743X - 1.441X^2$$

where Y = Weight gain (g/rabbit/day)

X = Level of BSR

The results show that feeding BSR at 20% dietary level gave the best feed to gain ratio. However, this was not significantly ($P>0.05$) better than that of the control. There was also no significant ($P>0.05$) difference obtained for feed efficiences between treatments 1,2,3 and 4. Diet 5 with 40% BSR gave significantly ($P<0.05$) poorer feed efficiency when compared with the values for all other treatment groups. Rabbits fed the 20% BSR diet required only 3.34kg of feed to produce 1kg of weight gain as against 9.33kg required by those fed 40% BSR diet. Similar findings reported by Alawa *et al.* (1990) indicated no significant differences in feed to gain ratio when BDG was fed up to 30% of the diets of rabbits. Omole and Ajayi (1976) also observed that feed efficiency of rabbits decreased only when 30% BDG was included in their diets. This poor feed to gain ratios at higher levels of BSR inclusion, is an indication of the poor nutritive value of the feed when BSR exceeds 20% of the diet.

When feed efficiency was regressed against dietary levels of BSR, the following prediction equation was obtained:

$$Y = 7.545 - 3.903X + 0.835X^2$$

where Y = Feed efficiency

X = Level of BSR

The costs of feed per kilogramme were found to decrease linearly ($P<0.05$) from N6.40 for the control diet to N2.70 per kilogramme of feed for the 40% BSR diet (Fig. 1d). Table 6 shows that the rabbits fed the 40% BSR diets were on a significantly ($P<0.05$) cheaper feed per kilogramme than those of other dietary treatments. This trend observed is due to the relacement of more of the expensive feed ingredients (maize and soyabean meal) in the diets by the relatively cheap BSR.

Feed cost per kilogramm was regressed against the dietary BSR levels and the following prediction equation obtained:

$$Y = 7.315 - 0.929X$$

where Y = Feed cost per kilogramme (N/kg)

X = Level of BSR

Table 6 shows that feed cost per kilogramme live weight gain decreased quadratically ($P<0.05$) as BSR level increased in the diets. Rabbits on the 20% BSR diets had the lowest feed cost per kilogramme live weight gain (N14.93), while treatment 1, the control, gave significantly ($P<0.05$) higher feed cost per kilogramme live weight gain. The regression equation obtained when feed cost per kilogramme live weight gain was regressed against dietary BSR levels was:

$$Y = 38.642 - 14.049X + 2.156X^2$$

where Y = Feed cost per kilogramme gain (N/kg gain)

X = Level of BSR

No mortalities were recorded for the groups of rabbits fed the 0, 10 and 20% BSR diets. Mortalities of 33.3% and 16.7% were however reported for rabbits on 30 and 40 % BSR diets respectively.

3.4.3 Effect of dietary levels of brewers' sorghum residue on carcass parameters.

The carcass characteristics of rabbits fed brewers' sorghum residue (BSR) based diets are shown in Table 7.

The dressing percentage decreased linearly as BSR levels in the diet increased. Rabbits on treatment 3 (20% BSR diet) dressed better than those on all other treatment groups. There were however no signicicant differences in the dressing percentages of rabbits fed 0, 10, and 20% BSR diets. The reduction in dressing percentage as BSR levels of the diet increased is as a result of the reduced feed intake and consequently reduced growth rate of these rabbits as BSR levels increased in their diets.

Significant differences ($P<0.05$) were also observed in gut plus cecum weight, gut length and abnominal fat content of rabbits as the level of BSR in the diets increased. Gut plus caeca weight increased linearly ($P<0.05$) as the level of BSR in the diets increased. This however disagrees with the reports of Dogari (1985) who observed a significant increase in gut weight and gut length as the level of sorghum beer residue increased from 10 to 60% in the diets of broiler

finishers. Pond *et al.* (1981) linked the bulky nature of high fibre diets with increase in weight/volume of the stomach and various segments of the gastro-intestinal tracts thereby resulting in incresed capacity of the gastro-intestinal tracts to accomodate more of large quantities of bulky materials. Since the fibre levels of the diets in this study fall within the range recommended for growing rabbits, the decrease in gut plus caeca weight and gut length could explained in line with the decrease in the feed intake of rabbits as BSR levels increased in the diets. Reduction in feed intake resulted in a reduction in the amounts of nutrients available at the tissue level for body biulding such that growth is greatly impaired.

Abdominal fat content reduced as BSR in the diets increased. This confirms the results of other authors who have reported a decrease in fat content as BDG increased in the diets of pigs and chikens (Aletor, 1986; Onwudike, 1983; Lopez *et al.*, 1981; Paliev, 1983). This is probably due to the decreased intake of feed and consequently decreased energy intake. In addition, the energy values of the BSR based diets decreased with dietary increase in BSR, such that rabbits on these diets were unable to eat sufficient amounts to meet their energy requirements let alone depositing any excess. Serres (1992) in a similar study found that meat in the carcass of pigs tended to increase while fat decreased with increasing amounts of brewers' grains in the diet. No

significant differences were obseved in liver weight and edible organ (liver, kidney, heart) weight. This agrees with the findings of Dogari (1985) who observed that liver and gizzard weights were not affected by dietary treatments when sorghum beer residue was included up to 50% in diets of broilers.

3.4.4 Effect of dietary levels of brewers' sorghum residue on nutrient digestibility.

The apparent nutrient digestibilities of the diets are presented in Table 8. No significant differences were observed in the digestibility coefficients of dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) or ash as the level of BSR in the diets increased. In a similar study, Babatunde *et al.* (1975) observed insignificant decreases in dry matter, energy, nitrogen, ether extract and crude fibre digestibility when diets containing 0 to 15% BDG were fed to growing rabbits. Yaakugh *et al.* (1988) however observed significant depressions in the digestibilities of dry matter, energy, nitrogen, ether extract, crude fibre and ash as the level of BDG replacing maize increased in the diets of pigs.

The digestibilities of DM, CP, EE and ash followed the same trend, insignificantly reducing with increase in the level of BSR fed in the diets. Alawa *et al.* (1990) however reported a significant decrease in the digestibility of dry

matter and organic matter as the level of BDG increased in the diet of rabbits. According to these authors, the decline in DM digestibility may be attributed to the increase in dietary levels of crude fibre as BDG levels increased in the diets. Crude fibre levels in this present study were however within the range recommended for growing rabbits. The difference in the nutrient digestibilities of the control and all other treatments, though insignificant, may be as a result of the difference in the level of feed intake of the rabbits. With increase in the level of BSR in the diets, feed intake reduced and this consequently resulted to a reduction in the amount of feed available for digestion. Another reason may be due to the bulkiness of the BSR based diets. Bulky diets tend to move more rapidly through the gut, thereby reducing retension time for enzmatic action and consequently lowering nutrient digestibility.

The digestibilities of crude fibre increased insignificantly ($P>0.05$) as the level of BSR increased from 10 to 40% in the diets of the rabbits. This was also not different from the control diet. Yaakuugh *et al.* (1988) reported a depression in crude fibre digestibility as the level of BDG replacing maize in the diets of pigs increased. The result in the present study confirms that rabbits in comparism to pigs and poultry, are able to handle high amounts of fibre due to the presence of micro-organisms in the cecum.

463224

The depression in the digestibilities of DM, CP, EE and ash observed in this study, can also be associated with the increasing level of tannin as the level of BSR increased in the diets. According to Burns and Cope (1974), tannin diminish the digestibility of dry matter and nitrogen. The reduction in the digestibility of tannin-rich feeds was explained on the basis of the inhibition of digestive enzymes (Bressani and Elias, 1979). The antinutritive effects of tannins have been attributed to their ability to form enzyme-resistant complexes with protein and carbohydrate (Van Soest, 1982; Liener, 1989). Also, as a result of tannins forming complexes with protein, enzyme reactions involved in digestion are retarded by direct inhibition of the enzymes themselves (Longstaff and McNab, 1991).

3.5 CONCLUSION.

The analyses showed that brewers' sorghum residue is rich in crude protein, high in fibre but low in minerals such as calcium and phosphorus. It is therefore advisable to determine the chemical composition of brewers' sorghum residue to be used in rabbit diets because of possible variations due to the source and method of processing which may affect the quality of the product.

The inclusion of brewers' sorghum residue from 0 - 40% levels in the diets of weaner rabbits resulted in a progressive decline in the energy content of the feed and an

increase in the level of tannin in the diets. The failure of rabbits on the high BSR diets to increase feed intake so as to compensate for the low energy level of the diets, led to the poor weight gains reported in this study. This low feed intake at 30 and 40% BSR levels respectively, was also associated with the unpalatable nature and high levels of toxic tannin in the diets. This consequently resulted in lower weight gains and depression in the digestibility of the feeds. Rabbits in this study performed satisfactorily on BSR diets up to 20% dietary levels when final weights, average daily gain, feed to gain ratio and mortality were considered. Furthermore, the 20% BSR diet tended to produce the best savings in cost of feed per kilogram gain. On the basis of these observations, it is recommended that brewers' sorghum residue (BSR) could be fed as a feeding ingredient up to 20% level in the diets of weaner rabbits.

Table 4. Composition and calculated analyses of diets.

	TREATMENTS				
	1	2	3	4	5
	Levels of BSR, %				
Ingredients	0	10	20	30	40
Maize	52.96	49.27	45.56	41.85	38.15
Soyabean meal	28.29	21.98	15.69	9.40	3.10
Brewers' sorghum residue	0.00	10.00	20.00	30.00	40.00
Rice offal	15.00	15.00	15.00	15.00	15.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Vitamin-mineral premix[1]	0.25	0.25	0.25	0.25	0.25
Salt	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Calculated analyses:					NRC Requirement
Crude protein, %	18.00	18.00	18.00	18.00	18.00
M.E., kcal/kg[2]	2679.66	2576.22	2473.57	2370.42	2267.38
Crude fibre, %	10.00	10.66	11.32	11.99	12.60
Ether extract, %	3.86	4.23	4.60	4.97	5.35
Lysine, %	0.96	0.83	0.83	0.73	0.64
Methionine + Cystine, %	0.56	0.57	0.58	0.59	0.60
Arginine, %	1.12	1.05	0.95	0.91	0.84
Calcium, %	1.16	1.17	1.17	1.17	1.17
Phosphorus, %	0.88	0.88	0.87	0.87	0.86
Tannin, %	0.00	0.60	1.20	1.81	2.41

[1]Vitamin-mineral premix supplied per kilogramme ration:- Vit.A 12511IU, Vit.D_3 2750IU, Vit.E 15IU, Vit.K 0.002g, Vit.B_1 0.0015g, Vit.B_2 0.006g, Nicotinic acid 0.035, Calcium D-Pantothenate 0.01mg, Vit.B_6 0.0035, Vit.B_{12} 0.02g, Folic acid 0.001g, Biotin 0.0005g, Vit.c 0.025g, Choline chloride 0.39g, Zinc bacitracin 0.02g, Methionine 0.2g Avatec (Lasolocid) 0.09g, manganese 0.1g, iron 0.05g, Zinc 0.04g, Copper 0.002g, Iodine 0.00153g, cobalt 0.000225g, Selenium 0.0001g.

[2]Metabolizable energy calculated using M.E. values for poultry.

Table 5. *Proximate composition of Brewers' sorghum residue (BSR) % DM.*

Nutrient	% DM
Dry matter	93.72
Crude protein	30.16
Ether extract	11.82
Crude fibre	12.93
Ash	2.51
NFE	42.58
Calcium	0.14
Phosphorus	0.43
Gross energy, Kcal/kg	4.92
Soluble tannins, %	6.02

Table 6. Performance of weaner rabbits fed graded levels of BSR.

Parameter	Level of BSR, % 0	10	20	30	40	SEM
Ave. int. wt., g	633.33	633.33	633.33	605.83	612.50	8.69
Ave. fin. wt., g	1300.00^{a}	1282.50^{a}	1341.67^{a}	1047.22^{b}	781.39^{c}	36.45
Daily wt. gain, g	15.09^{a}	15.47^{a}	16.87^{a}	10.50^{b}	3.86^{c}	0.95^{++}
Daily feed intake, g	64.06^{a}	61.21^{a}	55.87^{ab}	46.40^{b}	34.37^{c}	3.06^{+}
FCR	4.04^{b}	3.96^{b}	3.34^{b}	4.41^{b}	9.33^{a}	0.53^{++}
Feed cost/kg, N/kg	6.40^{a}	5.46^{b}	4.51^{c}	3.57^{d}	2.70^{e}	0.006^{+}
Feed cost/kg gain, N/kg gain	25.70^{a}	21.59^{b}	14.93^{c}	15.82^{d}	23.03^{e}	0.006^{++}
Mortality, %	0.0	0.0	0.0	33.33	16.67	7.57

^{abc}Means on the same row with different superscripts differ significantly ($P<0.05$)
SEM - Standard error of means
FCR - Feed to gain ratio.
$^{+}$Linear effect significant ($P<0.05$)
$^{++}$Quadratic effect significant ($P<0.05$)

Table 7. Carcass evaluation of weaner rabbits fed graded levels of BSR.

Parameter	Level of BSR, % 0	10	20	30	40	SEM
Dressing percentage, %	71.2^{a}	63.7^{ab}	72.9^{a}	56.7^{b}	52.8^{b}	2.78^{++}
Liver wt., g	43.3	55.0	60.0	43.3	35.0	9.42
Liver wt. (% body wt.)	2.3	3.3	3.8	3.6	3.8	0.46
Edible organ wt., % body wt.	3.8	4.2	5.0	5.2	5.2	0.57
Gut & cecum wt. (% body wt.)	5.8^{c}	6.2^{c}	7.3^{a}	7.2^{ab}	6.8^{b}	0.72
Gut length, cm	413.0^{a}	343.0^{b}	431.7^{a}	392.3^{ab}	345.0^{b}	21.44^{++}
Abdominal fat (% body wt.)	0.96^{a}	0.74^{ab}	0.51^{bc}	0.28^{c}	0.23^{c}	0.13^{+}

^{abc}Means on the same row with different superscripts differ significantly ($P<0.05$)
SEM - Standard error of means
$^{+}$Linear effect significant ($P<0.05$)
$^{++}$Quadratic effect significant ($P<0.05$)

Table 8. Apparent nutrient digestibility coefficients of BSR based diets.

Parameter	Level of BSR, % 0	10	20	30	40	SEM
Dry matter	0.79	0.76	0.75	0.75	0.76	0.03^{NS}
Crude protein	0.86	0.85	0.81	0.81	0.80	0.03^{NS}
Crude fibre	0.47	0.31	0.41	0.45	0.49	0.09^{NS}
Ether extract	0.91	0.92	0.91	0.88	0.81	0.03^{NS}
Ash	0.54	0.34	0.29	0.28	0.43	0.08^{NS}

^{NS} Not significant ($P > 0.05$).

CHAPTER FOUR

4.0 EFFECT OF GRADED LEVELS OF BREWERS' SORGHUM RESIDUE ON REPRODUCTIVE PERFORMANCE OF BREEDING DOES.

4.1 ABSTRACT

An experiment was conducted to determine the optimum level of brewers' sorghum residue (BSR) that can be included in the diets of breeding does without adverse effects on their reproductive performance. Forty five (45) does with an average initial weight of 1945g were used for this experiment. The does were alloted randomly to five dietary treatments. The diets were formulated to contain 18% crude protein and brewers' sorghum residue (BSR) was included at 0, 7.5, 15, 22.5 and 30 percent levels of the diets respectively. There were three replicates per treatment. All diets were iso-nitrogenous with 18% crude protein (CP). The trial lasted for six weeks covering a two week adaptaion period and four weeks gestaion period.

Average daily feed intakes of 135.5, 130.4, 117.6, 109.4 and 83.9g were significantly different ($P<0.05$) for does fed 0, 7.5, 15, 22.5 and 30% BSR diets respectively. Gestation gains of 344.4, 393.3, 417.8, 285.0 and 152.2g also significantly differ ($P<0.05$) as BSR levels increased in the diet. Gestation length, litter size at birth, litter birth weight, average kit birth weight and mortality of kits within the first week of life, were not affected by dietary

treatments. Does on the 15% BSR diet gained insignificantly (P>0.05) more weight during gestation and kindled more and heavier kits than does on the other treatment groups. This study indicated that BSR could be used in the diets of breeding does up to 15% level without detrimental effects on reproductive performance.

4.2 INTRODUCTION

It is generally agreed that cost of feeds accounts for about 60 - 85 percent of the total cost of livestock production. In the light of today's economic crunch, it has become critical to source for alternative feed ingredients which do not have competitive usage with man. It is hoped that these alternative feed sources will reduce the cost of livestock production in the country. Fetuga *et al*. (1974) stated that the lack of information on the composition and utilization of the many and varied protein sources indigenous to Africa was the major problem rather than a real shortage of the sources of protein. Tegbe *et al*. (1984) suggested that one means of increasing animal protein production in the developing countries was through the use of cheap and readily available agro-industrial by-products in the diets of our livestock.

Brewers' dried grains (BDG), an agro-industrial by-product is derived as the major by-product of the brewing industry (Bello, 1984). It is relatively high in fibre and

has been incorporated in the diets of pigs (Tegbe *et al.* 1983, 1985), cattle (Umoh *et al.*, 1982; Umunna *et al.*, 1980), chickens (Ademosun, 1973) and rabbits (Alawa *et al.*, 1990; Fonolla *et al.*, 1985). Levels of 20 and 30% BDG were reported to significantly reduce rate of gain of growing chickens (Ademosun, 1973). Other studies with growing pigs indicated BDG may supply up to 50% of the supplemental protein (23% of diet) *without significantly affecting rate of gain*, but this level reduced feed efficiency. Omole and Ajayi (1976) showed that BDG may be incorporated up to 15% in rabbit rations. Brewers' dried grain used in these experiments reported were basically barley-based. However, most brewing industries now produce a brewers' residue that is either maize or sorghum based (Aisien, 1989).

Since the effect of brewers' sorghum residue has not been determined in the diets of breeding does, this experiment was conducted to:

i. study the effect of graded levels of brewers' sorghum residue in the diets of breeding does.

ii. determine the effect of brewers' sorghum residue on overall feed cost.

4.3 MATERIALS AND METHODS

A total of forty five (45) does with an average initial weight of 1945g were used for this experiment. The does were allotted randomly to five dietary treatments. The diets were iso-nitrogenous formulated to contain 18% crude protein and brewers' sorghum residue (BSR) was included at 0, 7.5, 15, 22.5 and 30 percent levels in the diets respectively. There were three replicates per treatment. Rabbits were housed individually in cages measuring 60x50x45cm raised 100cm from the concrete floor. Does were individually fed 150g daily of a common diet for two weeks prior to mating, and fed ad libitum thereafter. They were then mated to bucks of same breed as the respective does. The composition and calculated analyses of the diets are given in Table 9.

Nine (9) sexually mature bucks (13 $\pm$ 0.5month old), maintained on a standard diet were used for breeding. A buck was mated to a total of five (5) does. The pregnant does were continued on their respective diets through gestation. Kits were weighed at birth using polythene bags to carry them to prevent rejection by the doe.

Records of feed intake, gestation gain (weight changes from day doe was mated to 25 days before kindling), gestation length, total number of kits born, litter weight of kits born, average weight of kits and mortality of kits within the first week of life were collated and subjected to analysis of variance and the differences between treatment means were

compared using Duncan's Multiple Range Test (Steel and Torrie, 1980). The trends were determined using curvilinear contrasts.

4.4 RESULTS AND DISCUSSION

The weight changes and reproductive performance of does fed graded levels of BSR are summarized in Table 10.

The results show an inverse relationship between feed intake and the level of inclusion of BSR in the diet. Average daily feed intake decreased linearly ($P<0.01$) as the level of BSR increased in the diet. Feed intake for the control diet was 133.5 as against 83.9 for the 30% BSR diet. Thus rabbits fed the 30% BSR diets consumed significantly ($P<0.05$) less feed than those on the control diet. There was however no significant ($P>0.05$) differences in feed intake of rabbits fed 0, 7.5 or 15% BSR diets. Udedibie and Emenalom (1993) reported in a similar finding that broilers fed a maize/sorghum based dried brewers' grain diet consumed significantly ($P<0.05$) less feed than those which received a commercial diet (control). However, Walhstrom and Libal (1976) reported an increase in feed intake of pregnant sows as BDG levels increased from 0 - 40% in their diets. A number of factors can be responsible for the differences observed in feed intake among treatments in this study. It has been reported that the unpalatable nature of brewers' grains reduces feed intake (Babatunde *et al.*, 1975). The decease in feed intake observed for does in this study may also probably

be due to the decrease in energy content of the diets as dietary BSR increased from 0-30%. In addition, tannin content of the diets tended to increase with increase in BSR inclusion in the diet. Kumar and Singh (1984) reported that non-palatability due to the astrigent tannins lead to a decrease in voluntary feed intake of birds.

The following equation was derived when feed intake of does was regressed against BSR levels.

$$Y = 140.15 - 1.65X$$

where Y = Feed intake (g feed/rabbit/day)

X = Level of BSR

Gestation gain (total weight gained by does from mating to 25 days of gestation) increased quadratically ($P<0.05$) with increase in level of BSR in the diet. Does on 15% BSR gained more weight duing gestation than those on the other treatment groups. Table 9 shows that the energy value of the diets decreased with increasing levels of BSR in the diet. Therefore increasing dietary levels of BSR consequently decreased the amount of energy available to the rabbits in the diet. This low energy levels coupled with the reduction in feed intake, resulted in the poor weight gains observed at higher levels of dietary BSR inclusion. Energy values for treatments 4 and 5 (22.5 and 30% BSR diet) were lower than the value of 2500kcal/kg recommended by NRC (1970). Similar findings were reported by Walhstrom and Libal (1976) who found that inclusion of BDG in the diets of pregnant sows above 20%

level resulted in significant decrease in gestation gain.

Gestation gain was regressed against BSR levels and the following prediction equation derived:

$$Y = 342.39 + 13.39X - 0.66X^2$$

where Y = Gestation gain (g)

X = Level of BSR

There was no significant ($P>0.05$) difference in the gestation lengths of does fed graded levels of BSR. Litter size, litter birth weight and average birth weight also did not significantly ($P>0.05$) differ among treatment groups. Litter size, litter birth weight and average birth weight seemed however higher for does which were fed 15% BSR diets than those fed the control or other treatment groups. This agrees with the report of Wahlstom and Libal (1976) who reported that litter size of live pigs and litter and individual pig weight at birth and weaning were not affected by gestation dietary level of BDG.

The result showed a non-significant effect of dietary levels of BSR on mortality of kits within the first one week of life. The highest mortality (15.9%) was however recorded for 7.5% BSR diet and the lowest (2.2%) for the 22.5% BSR diet. This however, may not be related to dietary treatments.

An inverse relationship was observed between feed cost and dietary levels of BSR. There was a linear decrease ($P<0.05$) in the total cost of feed as the level of BSR increased in the diets. The control diet was the most

expensive (N6.40/kg) while 30% BSR diet was the least expensive (N3.60/kg). When feed cost was regressed against dietary BSR levels the following prediction equation was obtained:

$$Y = 6.4 - 0.094X$$

where Y = Feed cost (N/kg)

X = Level of BSR

The result show that feed cost per kilogramme live weight gain decreased quadratically ($P<0.05$) as BSR levels in the diet increased. It costs the least to raise the weight of the doe by 1kg by feeding 15% BSR diet and the highest when the control diet was fed. The regression equation derived for predicting feed cost/kg gain is given as follows:

$$Y = 63.22 - 2.96X + 0.08X^2$$

where Y = Feed cost/kg gain (N/kg gain)

X = Level of BSR

The low feed costs were expected since the increase in levels of cheap brewers' sorghum residue used in the diets consequently reduced total feed cost by reducing the amounts of the expensive ingredients (maize and soyabean meal) used in the rations.

4.5 CONCLUSION

From the results obtained in this study, it can be concluded that:

1. The diets of pregnant does can contain up to 15% BSR without deleterious effect on their performance
2. The poor performance of does on diets containing high BSR levels could be attributed to the combined effects of low caloric value, bulky nature of the diets and their high tannin contents.
3. There is cost benefit effect in feeding brewers' sorghum residue to pregnant rabbits up to 15% of the diet.

Table 9. Composition and calculated analyses of diets.

	TREATMENTS				
	1	2	3	4	5
	Levels of BSR, %				
Ingredients	0	7.5	15	22.5	30
Maize	52.96	50.18	47.40	44.64	41.85
Soyabean meal	28.29	23.57	18.84	14.10	9.40
Brewers' sorghum residue	0.00	7.50	15.00	22.50	30.00
Rice offal	15.00	15.00	15.00	15.00	15.00
Bone meal	3.00	3.00	3.00	3.00	3.00
Vitamin-mineral premix[1]	0.25	0.25	0.25	0.25	0.25
Salt	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Calculated analyses:					NRC Requirement
Crude protein, %	18.00	18.00	18.00	18.00	18.00	18
M.E., kcal/kg[2]	2679.66	2602.30	2525.09	2437.85	2370.42	2500
Crude fibre, %	10.00	10.50	10.99	11.49	11.99	12
Ether extract, %	3.86	4.14	4.42	4.70	4.97	3
Lysine, %	0.96	0.88	0.81	0.74	0.73	0.75
Methionine + Cystine, %	0.56	0.56	0.57	0.58	0.59	0.59
Arginine, %	1.12	1.07	1.02	0.96	0.91	0.80
Calcium, %	1.11	1.13	1.15	1.16	1.19	1.10
Phosphorus, %	0.86	0.89	0.93	0.97	1.01	0.80
Tannin, %	0.00	0.45	0.90	1.35	1.81	

[1]Vitamin-mineral premix supplied per kilogramme ration:- Vit.A 12511IU, Vit.D_3 2750IU Vit.E 15IU, Vit.K 0,002g, Vit.B_1 0.0015g, Vit.B_2 0.006g, Nicotinic acid 0.035, Calcium D Pantothenate 0.01mg, Vit.B_6 0.0035, Vit.B_{12} 0.02g, Folic acid 0.001g, Biotin 0.0005g, Vit.C 0.025g, Choline chloride 0.39g, Zinc bacitracin 0.02g, Methionine 0.2g Avatec (Lasolocid 0.09g. manganese 0.1g, iron 0.05g, Zinc 0.04g, Copper 0.002g, Iodine 0.00153g, cobal 0.000225g, Selenium 0.0001g.

[2]Metabolisable energy calculated using M.E values for poultry.

Table 10. Effect of brewers' sorghum residue (BSR) on does' performance.

Item	Levels of BSR, %					
	0	7.5	15	22.5	30	SEM
Gestation gain, g	344.4^{ab}	393.3^{a}	417.8^{a}	285.0^{ab}	152.2^{b}	66.63^{++}
Ave. daily feed intake, g	135.5^{a}	130.4^{a}	117.6^{b}	109.4^{b}	83.9^{c}	6.28*
Litter size at birth	4.3	4.9	5.0	4.8	4.0	0.52
Litter birth weight, g	185.0	218.6	274.2	260.0	191.7	36.24
Ave. birth weight, g	42.3	44.8	57.3	52.9	48.4	5.01
Gestation length, days	30.0	32.0	32.7	31.6	31.7	0.89
Kit mortality, %	7.8	15.9	12.9	2.2	5.9	5.78
Feed cost/kg, N/kg	6.4^{a}	5.7^{b}	4.9^{c}	4.3^{d}	3.6^{e}	0.003*
Feed cost/kg gain, N/kg gain	62.9^{a}	47.2^{c}	35.1^{e}	41.1^{d}	49.2^{b}	0.003^{++}

^{abc} Means on the same row bearing different superscipt differ significantly ($P<0.05$)
SEM - Standard error of means.
*Linear effect significant ($P<0.05$)
$^{++}$Quadratic effect significant ($P<0.05$, 0.01)

CHAPTER FIVE

5.0 GENERAL SUMMARY AND CONCLUSION.

The objective of this study is to source for alternative and cheap feed ingredients which can be incorporated into the diets of growing and breeding rabbits without adverse effects in their diets. These alternative feed sources must not only be cheap, they must not have competitive usage with man. *Brewers' sorghum residue (BSR) fits well into this category.* Given the digestive strategy of the rabbit which allows for efficient utilization of fibrous feeds such as BSR by the retention of the non-fibrous components, BSR has a high potential as a feed ingredient for rabbits. Intensifying rabbit production side by side with other ruminant and monogastric animals, will also go a long way to improve the presently low per caput consumption of animal protein in the country. Ruminants which hitherto have received much attention in production, have a lower turnover rate and are slower to mature than the non-ruminants, rabbit, poultry or pigs.

The use of fibre in rabbit diets have a number of reasons, among which are the reduction in incidences of coccidiosis, fur chewing and aiding in digestion. When fibre source such as brewers' sorghum residue are used, B-complex vitamins, mineral and unidentified growth factors are added to the diets.

The results of the chemical analysis show that brewers' sorghum residue (BSR) is 93.72% dry matter, 30.16% crude protein, 11.82% ether extract, 12.93% crude fibre, 2.51% ash, 0.14% Ca and 0.43% P. The gross energy and tannin contents of brewers' sorghum residue is 4.92kcal/g and 6.02& respectively. The chemical composition of brewers' sorghum residue may however differ depending on the source and the grains used (Kafidiya, 1992 personal communications).

Two studies were carried out using weaner and breeding rabbits respectively. The diets in each of the study were iso-nitrogenous but not iso-caloric. The weaner rations contained 0, 10, 20, 30 and 40% brewers' sorghum residue while the rations for the breeding does contained 0, 7.5, 15, 22.5 and 30% brewers' sorghum residue respectively. The results obtained from these experiments show that:

1. Brewers' sorghum residue is a rich source of protein and other nutrients for rabbit growth.
2. Inclusion of brewers' sorghum residue in weaner rations reduced feed intake and feed cost per kilogramme of the feed.
3. Weight gain increased up to 20% BSR inclusion in the diet and thereafter decreased.
4. The 20% BSR diet also gave the best result in terms of feed conversion and feed cost per kilogramme liveweight gain.
5. BSR inclusion in the diet reduced dressing percentage,

gut length and abdominal fat content.

6. Inclusion of BSR had no significant effect on liver weight and edible organ weight.
7. Gut plus caecum weights increased as the level of BSR included in the diet increased up to 30%.
8. BSR inclusion in the diets of weaner rabbits had no significant effect on digestibilities of the various nutrients.
9. Inclusion of BSR in the diets of pregnant does had no effect on reproduvtive parameters such as gestation length, litter size at birth, litter birth weight, average birth weight and kit mortality.
10. Gestation gain was highest for rabbits on 15% BSR diets.
11. There was a savings in the cost of feed when BSR was included in the diets of both weaner and pregnant rabbits.

These studies have shown that without adjusting for energy, brewers' sorghum residue can be included at a level of 20% and 15% in the diets of weanling and breeding does respectively without adverse effects on performance. Beyond this levels, growth rate relative to the control diet will be significantly depressed. These levels reduced feed cost and hence cost of production of rabbits in areas where brewers' sorghum residue is available.

REFERENCES

Aduku, A.O. 1989. *Industrial utilization of sorghum in Nigeria:* Utilization of sorghum grain in livestock feeds. A symposium on current status and potentials of industrial uses of sorghum in Nigeria. ICRISAT (WASIP) and IAR, 3-6 Dec., 1989.

A.O.A.C. 1975. Association of Official Analytical Chemists. Official methods of Analysis. 12th Edition. Washington, D.C.

Adebowale, E.A. and Ademosun, A.A. 1981. Studies on the utilization of brewers' dried grains by sheep and goats. 1. Growth studies. Bull. Anim. Hlth Prod. Afr. 29:365-370.

Ademosun, A.A. 1973. Evaluation of brewers' grains in the diets of growing chickens. Br. Poultry Sci. 14:463-468.

Adeyanju, S.A. and Ilori, J.O. 1976. Utilization of brewers dried grains for beef cattle. Nig. J. Anim. Prod., 13:16-21.

Adu, I.F. 1985. Utilization of graded levels of brewers' dried grains by growing-finishing sheep. J. Anim. Prod. Res. 5(1):59-66

Aisien, A.O. 1989. Industrial utilization of Sorghum in Nigeria. Summary proceedings of a symposium on the current status and potential of industrial uses of sorghum in Nigeria. 4-6th Dec., 1989, ICRISAT, Kano.

Alawa, J.P.; Fishwick, G. and Hemingway, R.G. 1988. Fresh and dried brewers' grains as protein supplement to barley straw given to pregnant beef cows. Anim. Feed Sci. Technol. 19: 33-41.

Alawa, J.P.;Karibi-Botoye, D.T.; Ndukwe, F.O. and Berepubo, N.A. 1990. Effect of varying proportions of brewers' dried grains *on the growth performance of young rabbits*. J. Appl. Rabbit Res. 12:252-255.

Alawa, J.P. and Amadi, C. 1990. Voluntary intake and digestibility of diets containing corn cobs, brewers' dried grain and wheat bran by rabbits. J. Anim. Prod. 11(1):9-19.

Aletor, V.A. 1986. Some agro-industrial by-products and "wastes" in livestock feeding: A review of prospects and problems. World Rev. Anim. Prod., 22:35-41.

Alhassan, W.S. 1985. The potential of agro-industrial by-products and crop residues for sheep and goat production in Nigeria pp 165-184. In: Small Rum. Prod. in Ng., Proc. Natl. Conf. on Small Rum. Prod. October, 1985. Zaria, Nigeria.

Allen, W.R.; Stevenson, K.R. and Buchanan-Smith, J. 1975. Influence of additives on the short-time preservation of wet brewers' grains stored in uncovered piles. Can. J. Anim. Sci. 55:609-618.

Allen, R.D. 1986. Feedstuffs ingredient analysis table. Feedstuffs

Almquist, H.J. 1972. Protein and amino acids in animal nutrition. Pernick, S.B. and Company, New York.

Aribisala, A.O 1989. Industrial utilization of Sorghum in Nigeria. Summary proceedings of a symposium on the current status and potentialof industrial uses of sorghum in Nigeria. 4-6th Dec., 1989, ICRISAT, Kano.

Babatunde, G.M.; Fetuga, B.L.; Oyenuga, V.A. and Ayoade, A. 1975. The effects of graded levels of brewers' dried grains and maize cobs in the diets of pigs on their performance characteristics and carcass quality. Nig. J. Anim. Prod. 2:119-133.

Babatunde, G.M. 1986. Value of agro-industrial by-products and farm wastes in the feeding of pigs in Nigeria. 1. Wheat offals, groundnut shells, maize cobs and brewers dried grains. NAR (B) 56 No. 12.

Bagepalli, S; Narasinga, R. and Parbhavathi, T. 1980. Tannin content of foods commonly used in India and its influence on ionizable iron. J. Sci. food Agric. 33:89-96.

Bello, A.O. 1984. The use of agro-industrial by-products and farm wastes in livestock feeding. Nig. J. of Anim. Prod. 11 (1 & 2):20-31.

Borriello, S.P. and Carman, R.J. 1983. Association of iota-like toxin and Clostridium spiriforme with both spontaneous and anti-biotic-associated diarrhea and colitis in rabbits. J. Clin. Microbiol. 17:414-418.

Branckaert, R. 1976. Dried brewers grains for feeding table poultry in tropical regions. Rev. Elev. Vet. Pays. Trop. 20:595-600.

Bressani, R. and Elias, L.G. 1979. Proceedings of the symposium on Polyphenols in cereals and legumes. St. Loius, MO. June 1979,pg 61. In: Tannins: Their adverse role in ruminant nutrition. J. Agric. Food and Chem. Vol 32(3) 447-453 1984.

Burns, J.C. and Cope, W.A. 1974 Agron. J 66, 195 In: Tannins: Their adverse role in ruminant nutrition. J. Agric. Food and Chem. Vol 32(3) 447-453 1984.

Cebrian, M. and Swan, H. 1979. The digestion of protein in ensiled brewers' grains by sheep. Anim. Prod. 28:249.

Champe, K.A. and Maurice, D.V. 1983. Response of early weaned rabbits to source and level of dietary fibre. J. Anim. Sci. 56:1105-1114.

Chase, L.E.; Ingallis, J.C. and Sniffin, C.J. 1981. Brewers' grains as a protein sources for lactating dairy cows. Unpublished data, Cornell Univ., Ithaca, N.Y.

Cheeke, P.R. and Patton, N.M. 1978. Effect of alfalfa and dietary fibre on the growth performance of weanling rabbits. Lab. Anim. Sci. 28:167-172.

Cheeke, P.R. and Patton, N.M. 1980. Carbohydrate overload of the hindgut - a probable cause of enteritis. J. Appl. Rabbit Res. 3(3):20-23.

Cheeke, P.R., Grobner, M.A. and Patton, N.M. 1986. Fibre digestion and utilization in rabbits. J. Appl. Rabbit Res. 9:25-32.

Cock, C.W. 1977. The use of rangelands for future meat production. J. Anim. Sci. 45:1476-1482.

Connor, J.K.; Hurwood, I.S.; Burton, H.W. and Fuelling, D.E. 1969. Some nutritional aspects of feeding sorghum grain of high tannin content to growing chicks. Aust. J. Exp. Agric. and Anim. Husb. 9:497-501.

Convard, H.R. and Moxon, A.L. 1979. Transfer of dietary selenium to milk. J. Anim. Sci. 62:404.

Crickenberger, R.G. and Johnson, B.H. 1982. The effect of feeding wet brewers' grains to beef heifers on wintering performances, sreum selenium and reproductive performance. J. Anim. Sci. 54:18-22.

Dale, N.M., Wyatt, R.D. and Fuller, H.L. 1980. Additive toxicity of aflatoxin and dietary tannins in broiler diets. Poul. Sci. 59 (11) 2417-2420.

Deltoro, L.J. and Fernandez, C.J. 1981. Evaluation of brewers dried grains in the diets of broiler chicks. Animal Feed Science & Tech.6 (2) 179-188.

Deltoro, L.J. Fernandez, C.J. and Martinez Pascal, J.L. 1981. Evaluation of brewers dried grains in the diets of broiler chicks. Animal Feed Science & Tech.6 (2) 179-188.

Dogari, M. 1985. Evaluation of local Sorghum beer residue in broiler chickens. M.Sc. thesis submitted to the Dept. of Animal Science, A.B.U., Zaria.

FDLPCS 1992. Nigerian National Livestock survey. Federal Department of Livetock and Pest Control Services, Abuja. Vol 2 pg. 289.

Featherstone, W.R. and Rogler, J.C. 1975. Infuence of tannins on the utilization of sorghum grain in rats and chicks. Nutr. Rep. Int. 11:491-497.

Fetuga, B.L.; Babatunde, G.M. and Oyenuga, V.A. 1974. Some Nigerian protein concentrates as foods and feeds. Nig. J. Anim. Prod. 1 (2):132-142.

Fonolla, J.; Sanz Sampelayo, R.; Escandon, V. 1985. Use of industrial by-products in the feeding of herbivorous animals. 2. Brewers grains. NAR(B) vol 55, No.6.

Garner, R.T.W. and Hurwood, I.S. 1976. Aust. Vet. J. 52, 194. In: Tannins: Their adverse role in ruminant nutrition. J. Agric. Food and Chem. Vol 32(3) 447-453 1984.

Harris, D.J. 1983. The digestion trial. J.Appl. Rabbit Res. 6(4):148.

Ibrahim, I.K.; Al-Talib, A.A.; Kloor, I.S. and Alhafio, M.A. 1986. Evaluation of brewers died grains in broiler diets. J. Agric. and Water Resources Research, Animal Production, 5(1):265-273.

Ikediobi, C.O.; Olugboji, O and Okoh, P.N. 1987. Cyanide profile of component parts of sorghum sprout. In: Aduku, A.O. 1989. Industrial utilization of sorghum in Nigeria: Utilization of sorghum grain in livestock feeds. A symposium on current status and potentials of industrial uses of sorghum in Nigeria. ICRISAT (WASIP) and IAR, 3-6 Dec., 1989.

Jensen, L.S., Chang, C.H. and Maurice, D.V. 1976. Improvement in interior egg quality and reduction in liver fat in hens fed brewers dried grain.

Jensen, L.S. 1981. Distillers feeds in poultry feeding. Poultry Digest, September, 1981 pg. 482.

Kafidiya, A. 1992. Use of sorghum and maize in the production of lager beer. Nigerian Breweries Plc., Kaduna.

Kenelly, J.J. and Aherne, F.X. 1980. The effect of fibre addition to diets formulated to contain different levels of energy and protein on growth and carcass quality of swine. Can. J. Anim. Sci. 60:383-393.

Kingsell, L.T.; Prentiss, N. and Lindsey, S.E. 1979. Protein and fibre enrichment of cookie flour with brewers' spent grains. Cereal chem. 56: 261-269.

Kubiczek, R.P.; Obilana, A.T. and Okoh, P.N. 1984. Improvement of the nutitional quality of Nigeria grain sorghum for human food: Pre-germination effect on quality of proteins. Paper presented at Ann. Conf. of Nig. Inst. of Food Science and Tech, O.A.U., Ile-Ife.

Kumar, R. and Singh, M. 1984. Tannins: Their adverse role in ruminant nutrition. J. Agric. Food and Chem. Vol 32(3) 447-453.

Laplace, J.P. 1978. Gastro-intestinal transit in monogastric animals. III. Feeding behaviour (feed intake-caecotrophy), gastro-intestinal motility and transit, and pathogeny of diarrhoea in the rabbit. Ann. Zootech. 27:225-265.

Laplace, J.P. and Lebas, F. 1977. The digestive transit in the rabbit. VII. Effects of grinding fineness of the feed ingredients before pelleting. Ann. Zootech. 26:413-420.

Lebas, F.; Roudert, P; Rouvier, R.and Rochambeau, H.de 1986. The Rabbit: Husbandry, health and production. FAO, USA animal production and Health Series, no. 21.

Lilly, V.; Birch, M. and Garascadden, P. 1980. The preservation of spent brewres grains by the application of intermediate moisture food tecnology. J. Sci. Food Agric. 31:1059-1065.

Lopez, D.J. and Carmona, F.J. and Pascal, M.J. 1981. Evaluation of brewers' dried grains in the diets of laying hens. Anim. Feed Sci. Technol. 6:169-178.

Lopez, D.J. and Carmona, F.J. 1981. Evaluation of brewers' dried grains in the diets of broiler chickens. Anim. Feed Sci. Technol. 6:179-188.

Lufadeju, E.A. and Olorunju, S.A.S. 1986. The ruminal degradation of some agro-industrial by-products. J. Anim. Prod. Res. 6: 161-170.

Maertens, L., Moermans, R. and De Groote, G. 1984. Digestibility and digestible energy content of a number of feedstuffs for rabbits. Proc. III Wld Rabbit Cong. I:244-251, Rome, Italy.

Maertens, L., Moermans, R. and De Groote, G. 1990. Prediction of the apparent digestible energy (ADE) content of commercial pelleted feeds for rabbits. J. Appl. Rabbit Res.

Madubuike, F.N. 1988. the effects of inclusion of graded levels of brewers dried grains in the diets of early-weaned pigs on their performance up to 10 weeks of age. Nig. J. Anim. Prod. 15:37-42.

Malomo, O. 1989. Sorghum in lager beer production : Progress and prospects. Summary proceedings of a symposium on the current status and potential of industrial uses of sorghum in Nigeria. 4-6th Dec., 1989, ICRISAT, Kano.

McLean, C.W. 1960. A survey of the nutritive value of brewery and distillery by-products. Vet. Rec. 84:572-575.

McLeod, M.N. 1974. Nutr. Abst. Rev. 44:804.

Mitjavila, S; Lacomber, C.; Carrera, G.; Devache, R. J. Nutr. 1977. 47,198. In: Tannins: Their adverse role in ruminant nutrition J. Agric. Food and Chem. Vol 32(3) 447-453 1984.

Mowat, D.N. 1980. Opportunity feeds for animals. Feedstuffs 52 (25):32-46.

Myers, D.F. and Ollier, A. 1962. Brewers grains storage trial at Pakeham. NAR (B) 33:2162.

NATIONAL RESEARCH COUNCIL (NRC). 1977. Nutrient Requirements for of rabbits. 6th edition. National Academy of Science, Washington, D.C.

NATIONAL RESEARCH COUNCIL (NRC). 1978. Nutrient Requirements for of poultry. 6th edition. National Academy of Science, Washington, D.C.

Nelson, T.S.; Stphenson, E.L.; Burgos, A.; Flayed, J. and York, J.O. 1975. Effect of tannin content on dry matter digestion and average amino acid availability of hybrid sorghum grains. Poult. Sci. 54:1620-1623.

Nelson, F.S. 1984. Replacement of maize in poultry diet with wheat offals and brewers' dried grains. M.Sc. thesis, A.B.U., Zaria.

Okoh, P.N.; Obilana, A.T.; Njoku, P.C. and Aduku, A.O. 1989. Proximate analysis, amino acid composition and tannin content of improved Nigerian sorghum varieties and their potential in poultry feeds. Anim. Feed Sci. and Tech. 7:359-364.

Olomu, O.S. 1988. Determination of the chemical composition of brewers' dried grains. NAPRI Annual Report 1988.

Olomu, J.M. 1984. Industrial by-products as alternative to maize in poultry rations. 1984. NAPRI Seminars Vol. 6, 1984.

Omole, T.A. and Ajayi, T.A. 1976. Evaluation of brewrs' dried grains in diets of growing rabbits. Nutr. Rep. Int. 13:383-387.

Onwudike, O.C. 1983. Brewers dried grains in the diets of broiler chickens. Nutr. Rep. Int. 28 (55):1165-1170.

Oster, A.; Thomke, S. and Gyallang, H. 1977. A Note on the use of brewers' dried grains as a protein feedstuff for cattle. Anim. Prod. 24:279-282.

Paliev, K.H.; Ilieva, I.; Kanev, S.; Klisurov, K.H.; Stancheva, M. 1983. Dried brewers' grains in mixed feeds for fattening pigs. NAR (B) Vol 53 No. 9 Abs.4749.

Patton, N.M.; Holmes, H.T. and Cheeke, P.R. 1983. Hairballs and pregnancy toxemia. J. Appl. Rabbit Res. 6:99.

Perry, T.W. 1980. Junk foods: Indusrial by-products for cattle. Feedstuffs. 52 (14):26-27.

Pond, W.G. and Maner, J.H. 1974. Swine production in temperate and tropical environments. W.H. Freeman and Company. San Franscisco, California.

Pond, W.G.;Yen, J.T.; LInd-Wall, R.N. and Hill, D. 1981. Dietary alfalfa meal for genetically obese and lean pigs. Effect on body weight gain, carcass and gastro-intestinal tract measurements and blood metabolite. J. Anim. Sci. 51: 367-373.

Pote, L.M.; Cheeke, P.R. and Patton, N.M. 1980. Utilization of diets high in alfalfa meal by weanling rabbits. J. Appl. rabbit Res. 3(4):5-10.

Preston, R.L.; Vance, R.D. and Cahill, V.R. 1973. Energy evaluation of brewers grains for gorwing and finishing cattle. J.Anim. Sci. 37 (1):174-178.

Preston, R.L. and Moxon, A.L. 1973. Response of growing-finishing steers to injected selenium. Ohio Agric. Rec. Dev. Centre. Beef Dairy Rep. 25.

Quemere, P.; Fourdrinier, R.; Lefranc, A.; Willequet, F. 1983. Utilization of dried brewers grain by growing-finishing pigs. NAR (B) Vol 53 No. 10 Abs. 5191.

Rostagno, H.S.; Featherstone, W.R. and Rogler, J.C. 1983. Studies on the nutritional value of sorghum grains with varying tannin content for chicks. I. Growth studies. Poult. Sci. 52:765-772.

Schlolaut, W. 1985. A compedium of rabbit production appropriate for conditions in developing countries. GTZ publication No. 169. Fed. Rep. of Germany.

Schlolaut, W. and Lange, K. 1985. In : A compedium of rabbit production appropriate for conditions in developing countries. GTZ publication No. 169. Fed. Rep. of Germany.

Sedam, R. 1957. Brewers production. In: The hanbook of feedstuffs - production, formulation and medication. Springer, New York. pg.66.

Serres, H. 1992. Manual of pig production in the tropics. CTA Technical Centre for Agricultural and Rural Co-operation. Translated by Julian Wiseman. CAB International pg 2-5.

Sharkey, M.J. 1973. Comparisons of the efficiency of energy and nitrogen retention in weaned lambs and rabbits. III. World Conf. Anim. Prod. Vol.1, Melbourne.

Singh, K.S. 1988. Poultry Nutrition. Kalyani Publishers, New Delhi pp.270-271.

Smith, O.B. 1984. Studies on the feeding value of agro-industrial by-products for livestock. Iv: The economics and feasibility of feeding cocoa-pods to ruminants. World Rev. of Animal Prod. Vol 20 No.1 pg. 61-66.

Spreadbury, D. and Davidson, J. 1978. A study of the need for fibre by the growing New Zealand White rabbit. J. Sci. Fd. Agric. 29:640-648.

Spedding, C.R.W. 1975. The biology of Agricultural systems. Acad. Press, London.

Steel, R.G.D. and Torrie, J.H. 1980. Principles and procedures of Statistics. McGraw-Hill Book Company Inc., New York.

Sullivan, T.W.; Kuhl, J.R. and Aolder, D.P. 1978. Evaluation of brewers dried grains and yeast in turkey diets. Poultry Science 57:1329-1330.

Sunde, T.W.; Kuhl, J.R. and Aolder, D.P. 1978. Evaluation of brewers dried grains and yeast in turkey diets. Poultry Science 57:1329-1330.

Tangle, H.L.; Penzes, L. and Doby, I. 1960. Effect of brewers in producing infertility of cows. Allaltenyesztes. 9:211-218.

Taylor, St. C. 1980. Liveweight growth from embryo to adult in domesticated mammals. Anim. Prod. 31:223-235.

Tegbe, T.S.B. 1983. Brewers' dried grains in the diets of growing-finishing pigs. Paper: 8th Annual Conf. Nig. Soc. Anim. Prod. Port Harcourt, Nigeria.

Tegbe, T.S.B. 1985. The effect of feeding iso-nitrogenous brewers' dried grain diets on the performances of different classes of pigs. Nig. J. Anim. Prod. 12 (1):49-56.

Tegbe, T.S.B., Jegede, J.O. and Adamu, I.S. 1995. The feeding value of local brewers' spent grain (BKT) waste. NAPRI Annual Report 1994-1995.

Udedibie, A.B.I. 1984. Brewers' dried grains as feedstuff for milk production - A Review. J. Anim. Prod. Res., 4:43-55.

Udedibie, A.B.I. and Emenalom, O.O. 1993. Preliminary observations on the use of maize/sorghum based brewers' grains fortified with palm oil for finishing broilers. Nig. J. Anim. Prod. 20 (1&2):104-110.

Umoh, J.E.; Lufadeju, E.A. and Olayiwole, M.B. 1982. The feed value of brewers' dried grains in ruminant fattening rations. NAPRI Annual Report, June, 1982.

Umunna, N.N.; Yusuf, A.A.; Aganga, A.A. 1980. Evaluation of brewers dried grain and palm kernel meal as major sources of nitrogen for growing cattle. Trop. Anim. Prod. 5(3):239-247.

Vohra, P.; Kratzer, F.H. and Joslyn, M.A.1966. The growth depressing and toxic effects of tannins to chicks. Poult. Sci. 46:132-142.

Voris, L., Marcy, F.L., Thacker, J., Waino, W.W. 1940. Digestible nutrients of feeding stuffs for the domestic rabbit. J. Agric. Res. 61: 673 - 684.

Wahlstrom, R.C. and Libal, G.W. 1976. Brwers' dried grains as nutrient source in diets of pregnant sows. J. Anim. Sci. 42:81-875.

Yaakugh, I.D.I.; Tegbe, T.S.B.; Olorunju, S.A.S.; Aduku, A.O. and Njoku, P.C. 1988. The digestibility of nutrients by young pigs fed diets in which brewers' dried grains replaced maize. *Nig. J. Anim. Prod.* 15 (1&2):49.

APPENDICES

Appendix 1: ANOVA for final weight for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	669688.956	167422.239	42.01
Error	10	39855.785	3985.579	
Total	14	709544.741		

Appendix 2: ANOVA for weight gain for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	354.0167	88.504	32.77
Error	10	27.0098	2.7009	
Total	14	381.0266		

Appendix 3: ANOVA for daily feed intake for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	1749.544	437.386	15.60
Error	10	280.461	28.046	
Total	14	2030.005		

Appendix 4: ANOVA for feed conversion ratio for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	71.583	17.896	21.24
Error	10	8.427	0.843	
Total	14	80.010		

Appendix 5: ANOVA for feed cost/kg for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	25.898	6.475	64745.10
Error	10	0.001	0.0001	
Total	14	25.899		

Appendix 6: ANOVA for feed cost/kg gain for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	261.442	65.360	99999.99
Error	10	0.001	0.0001	
Total	14	261.443		

Appendix 7: ANOVA for mortality for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	1	0.133	0.133	0.60
Error	3	0.667	0.222	
Total	4	0.8		

Appendix 8: ANOVA for percent mortality for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	1	83.333	83.333	0.60
Error	3	416.667	138.889	
Total	4	500.0		

Appendix 9: ANOVA for dressing percentage for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	714.402	178.601	4.54
Error	10	393.562	39.356	
Total	14	1107.964		

Appendix 10: ANOVA for liver wt as % of live weight for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	4.844	1.211	1.81
Error	10	6.673	0.667	
Total	14	11.517		

Appendix 11: ANOVA for gut weight % of live wt. for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	610.809	152.702	13.27
Error	10	115.086	11.509	
Total	14	725.896		

Appendix 12: ANOVA for abdominal fat wt % of live wt for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	1.1403	0.285	6.39
Error	10	0.4461	0.045	
Total	14	1.586		

Appendix 13: ANOVA for edible organ wt % of live wt. for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	5.297	1.324	1.35
Error	10	9.8	0.98	
Total	14	15.097		

Appendix 14: ANOVA for dry matter digestibility coefficient for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	0.013	0.003	1.01
Error	15	0.049	0.003	
Total	19	0.062		

Appendix 15: ANOVA for crude protein digestibility coefficient for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	0.012	0.003	1.14
Error	15	0.039	0.003	
Total	19	0.051		

Appendix 16: ANOVA for crude fibre digestibility coefficient for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	0.092	0.023	0.81
Error	15	0.428	0.029	
Total	19	0.520		

Appendix 17: ANOVA for ether extract digestibility coefficient for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	0.019	0.005	1.26
Error	15	0.057	0.004	
Total	19	0.076		

Appendix 18: ANOVA for ash digestibility coefficient for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	0.269	0.067	3.00
Error	15	0.337	0.022	
Total	19	0.607		

Appendix 19: ANOVA for nitrogen free extract digestibility coefficient for experiment 1.

Source of variation	DF	SS	MS	F
Treatment	4	0.004	0.001	0.85
Error	15	0.016	0.001	
Total	19	0.019		

Appendix 20: ANOVA for litter size for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	4.209	1.052	0.64
Error	25	40.990	1.639	
Total	29	45.2		

Appendix 21: ANOVA for birth weight for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	37177.619	9294.405	1.19
Error	25	195289.881	7811.595	
Total	29	232467.5		

Appendix 22: ANOVA for average birth weight for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	890.545	222.636	1.49
Error	25	3732.687	149.307	
Total	29	4623.232		

Appendix 23: ANOVA for gestation length for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	25.811	6.453	1.33
Error	26	125.867	4.841	
Total	30	151.677		

Appendix 24: ANOVA for gestation weight gain for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	402946.212	100736.553	2.58
Error	39	1521133.333	39003.419	
Total	43	1924079.545		

Appendix 25: ANOVA for percent mortality for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	1084.944	271.236	0.90
Error	40	12042.822	301.0706	
Total	44	13127.766		

Appendix 26: ANOVA for average daily feed intake for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	14902.763	3725.691	10.51
Error	40	14184.009	354.600	
Total	44	29086.772		

Appendix 27: ANOVA for feed cost/kg for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	44.987	11.247	99999.99
Error	40	0.003	0.000075	
Total	44	44.989		

Appendix 28: ANOVA for feed cost/kg gain for experiment 2.

Source of variation	DF	SS	MS	F
Treatment	4	3920.036	980.009	999.99
Error	40	0.003	0.00008	
Total	44	3920.039		

Appendix 29. Prices of ingredients at the time of the experiments (1993).

Ingredients	Price per tonne (N)
Maize	4,200
Soyabean cake	15,000
Rice offal	300
Brewers sorghum residue	1 ,500
Bone meal	1,800
Salt	7,600
Premix	128,000

Appendix 30. Calculation of apparenet nutrient digestibility coeffients.

The digestion trial and the calculation of the nutrient digestibility coefficients are according to the procedures given by Harris (1983). Basically, the principle of the digestion trial measures the amount of a particular nutrient that is digested and absorbed from the digestive tract. The method of determining how much is absorbed involves measuring how much of a particular nutrient is consumed by the animal and how much of the nutrient is excreted in the faeces. The nutrient digestibility coefficient is therefore given as follows:

$$\% \text{ Digestibility} = \frac{\text{Amount consumed - Amount in faeces}}{\text{Amount consumed.}}$$