THE EFFECTS OF ADDING MAIZE BRAN TO FINISHER FEED ON PERFORMANCE OF ARBOR ACRES AND COBB 500 BROILERS.

by

MARTHA NAMPOSYA MUSUKWA

A dissertation submitted to the School of Agricultural Sciences of the University of Zambia in partial fulfillment of the requirement of Master of Science in Animal Nutrition (Animal Science).

THE UNIVERSITY OF ZAMBIA
LUSAKA

DECLARATION.

I, MARTHA NAMPOSYA MUSUKWA, DECLARE THAT THIS DISSERTATION REPRESENTS MY OWN WORK AND THAT IT HAS NOT PREVIOUSLY BEEN SUBMITTED FOR A DEGREE AT THIS OR ANY OTHER UNIVERSITY.

Signature:  Date: 31-10-2000

APPROVAL.

This dissertation of Ms Martha Namposya Musukwa is approved as fulfilling part of the requirement for the award of the degree of Master of Science in Animal Nutrition (Animal Science) by the University of Zambia.

Examiner's name and signature. Date.

1. _____ 31/10/2000

Dr. D. B. NYIRENDA
(Advisor)

2. _____ 31/10/2000

Dr. F.M. HAAZELE
(Internal Examiner)

3. _____ 11th August 2000

Dr. JOSEPH SIMBAYA
(External Examiner)

ABSTRACT

The effects of 0%, 10%, 20% and 30% maize bran levels in broiler finisher diets, on the performance of Arbor acres and Cobb 500 broilers was investigated. Diets containing different levels of maize bran were introduced at 29 and 35 days of age. The test diets were fed *ad lib* up to the 47th day of growth in a 3 factor (2 strains x 2 feeding dates x 4 maize bran levels) Randomised Complete Block design arrangement having experimental units of 20-24 birds in 3 replications.

There were highly significant differences *($P \leq 0.01$)* between Arbor acres and Cobb 500 for all weighed parameters (liveweight, feed consumption, feed conversion ratio, dressed weight, dressing out %, weights of liver, gizzard and proventriculus, small intestine, colon, caeca, and abdominal fat, indicating the two were distinct strains. There were no significant differences among birds of the same strain, in liveweight, feed consumption, feed conversion ratio and dressed weight for the four levels of maize bran in the diet and the two starting dates for feeding the diets containing bran. Birds of both strains that were fed diets containing maize bran from day 29 had higher *($P \leq 0.01$)* abdominal fat weights than those fed from day 35.

Gastrointestinal tract (GIT) morphological changes were induced by feeding the 20% and 30% maize bran containing diets. Histological analysis of the ileum showed a proliferation of goblet cells in birds fed the 20% and 30% maize bran containing diets which increased mucous secretion for GIT protection against the abrasive action of the maize bran.

Dry matter apparent digestibility for both strains decreased linearly ($p \leq 0.05$) with increase in maize bran levels in the diet. In Arbor acres, apparent digestibility of CP, NDF and P; and AME decreased curvilinearly from 0% to 20% maize bran level and then increased up to the 30% maize bran level, indicating an improvement in efficiency of digestion of the diet containing 30% maize bran. In Cobb birds apparent digestibility of CP and NDF; and AME decreased linearly from 0% to 30% maize bran level. Total amounts of EE apparently digested in both Arbor acres and Cobb 500 birds increased

with increase in maize bran levels in the diet, enabling more efficient utilization of energy and improved efficiency of nutrient utilization.

Birds fed finisher feed containing 20% and 30% maize bran gave higher *($P \leq 0.01$)* gross margin returns than those at 0 and 10% levels. It can therefore, be concluded that adding 20% and 30% maize bran to the basal finisher improves profit margins without significantly affecting growth and feed utilization in Arbor acres and Cobb broiler strains.

DEDICATION

To my daughter Chileshe Nabonga and my son Mwila Theodore.

In memory of my late father Andrew Brighton Musukwa who died on 10th June, 1999.

To the Lord God Most High, Yahweh, The Great IAM, who makes all things possible.

ACKNOWLEDGEMENTS

Great appreciation for the invaluable guidance afforded me by my principal research advisor, Dr. D.B. Nyirenda as well as her co-advisors, Dr. F.M. Haazele and Dr. M.T. Daura.Great thanks to the Privatisation Support Unit of the Department of Research and Specialist Services (Ministry of Agriculture Food and Fisheries) who were the major sponsors of the research. Great thanks to the management of Hybrid Poultry Farm and Caledonian Hatcheries, both of Lusaka for providing the research chicks through the University of Zambia Department of Animal Science.

Many thanks to all the staff of the Animal Science Department who worked with me as one big team in support of the numerous activities that were required to achieve the research objectives. I would like to express my sincere gratitude to the Food Science Department for its contibution toward the analytical and histological analyses. Great thanks to Professor Pandey of the Department of Clinical studies, for his assistance in the immense task of preparation and interpretation of histological slides.

May I acknowledge that without the care and support of my sister Dr. P. Musukwa-Sambo and my brother Andrew M. Musukwa I would physically not have been able to continue with the research after I was involved in the fatal road traffic accident of 26th April, 1999.

Finally I thank God for placing all the right people in the right places at the right time.

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS.

AME	Apparent metabolizable energy
ANOVA	Analysis of variance
AOAC	Association of Analytical Chemists
CP	Crude protein
DM	Dry matter
DNA	Deoxyribonucleic acid
D.OUT	Dressing out
EE	Ether extract
FCR	Feed conversion ratio
GIT	Gastrointestinal tract
GE	Gross energy
G+P	Gizzard and proventriculus
L. WT	Liveweight
NDF	Neutral detergent fiber
NSP	Non-starch polysaccharides
SI	Small intestine
UV	Ultra-violet
UNZA	University of Zambia

LIST OF TABLES.

LIST OF FIGURES.

Page

LIST OF APPENDICES

Page

CHAPTER I

1.0 INTRODUCTION.

1.1 GENERAL.

Maize bran is produced as a by product of dry milling of maize (Zea mays L.). Zambia is one of the few countries in the world where maize is a primary source of carbohydrates for humans. Maize bran is therefore, available in abundance and at low prices (10 to 15 % the price of maize per Kg). Maize bran is one of the cheap feed ingredients that Zambian farmers have incorporated into broiler feed in an attempt to reduce feed costs and improve profit margins. There is however, hardly any mention in literature of the incorporation of maize bran in poultry diets and guidelines on the feeding of maize bran to broilers are lacking. Thus the use of the bran by farmers has been done without professional guidance. The various strains of broiler chickens available on the Zambian market have been subjected to these farm mixed feeds, without consideration of the genetic variation of the birds and subsequent variation in response of the birds to different levels and different stages of incorporation of maize bran in the diet.

The high cell wall polysaccharide content of maize bran qualifies it as a source of dietary fibre. As with other sources of dietary fibre, maize bran is expected to have diverse effects on the digestive system and process of digestion in non-ruminants, including chickens. It has been observed that up to limited levels, fibre is increasingly tolerated with the age of birds, without performance being affected. However, most of the experimental work on dietary fibre has been carried out on other cereal by products and not on maize bran. Scientific findings on the digestibility of fibre and its effects on nutrient digestion and absorption; gastrointestinal morphology, motility and microflora may therefore, not be the same or may vary to different extents for maize bran. The performance of broilers on diets having different levels of maize bran may, therefore not be the same as when other cereal bran is added at same levels.

1.2 OBJECTIVES

The objectives of this study, therefore, were:

i) To compare the effect of adding different levels of maize bran to finisher feed on the growth of Arbor Acres and Cobb 500 strains of broilers.

ii) To measure the effect of adding different levels of maize bran to broiler diets on apparent digestibility of dry matter, protein, lipids, neutral detergent fibre, calcium and phosphorus; and on metabolizable energy.

iii) To observe the effects of different levels of maize bran on morphology and microflora colonisation of the gastrointestinal tract.

iv) To find out efficient feeding levels of maize bran in broiler feeds, from 29 and 35 days to 47 days.

CHAPTER II.

2.0 LITERATURE REVIEW.

It is generally accepted that cereal dietary fibre contains factors which reduce feed intake and depress poultry performance *(Saito et al., 1959; MacAuliffe and Mcginnis, 1971; Wagner and Thomas, 1977; Gohl et al., 1978; Day and Thomas, 1980; Antoniou and Marquardt, 1981; Hesselman and Aman, 1986; Saunders, 1986;). Nahm and Carlson (1985)* while working with broiler chicks found that supplementation of a 20% wheat bran diet with Trichoderma viride cellulase resulted in an increase in feed consumption. *Ward and Marquardt (1987)* reported that the bran fraction of rye more effectively depressed feed than the flour portion in white leghorn cockerels. *Kratzer et al. (1974)* reported that growth of chicks was depressed by approximately 30% when rice bran was used at 60% of the diet to replace maize as an energy source.

To understand the digestibility of dietary fibre and its effect on the digestion and absorption of other nutrients, it is necessary to know the composition of dietary fibre, processes by which it is degraded and the behaviour of the products of degradation in the digestive tract. Dietary fibre, mainly in poultry diets, is reviewed with reference to maize bran where information is available.

2.1 DIETARY FIBRE IN POULTRY DIETS

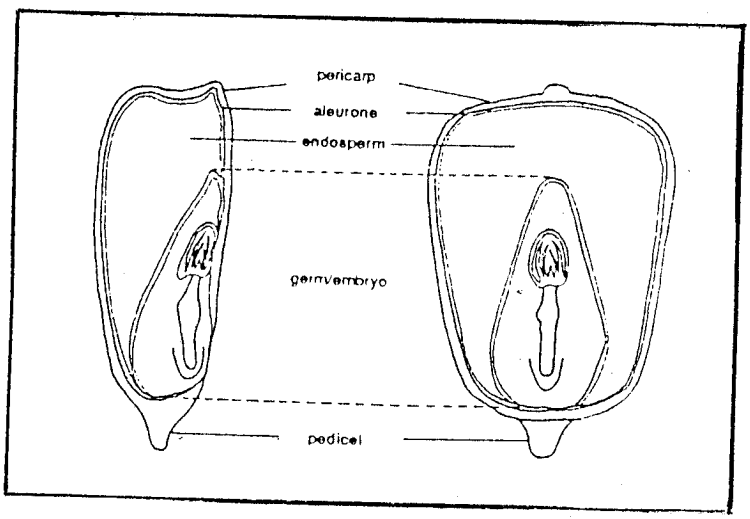
2.11 Composition of Dietary Fibre

Dietary fibre is a heterogenous mixture of structural (cellulose, hemicellulose and pectin) and non-structural (gums, mucilages and algal types) polysaccharides and lignin *(Low, 1985; Englyst, 1989; Potkins et al., 1991).* The cellulose fraction consists of long chains of glucopyranose residues, hemicellulosic polysaccharides are typically rich in xylose, and pectic polysaccharides are rich in galacturonic acid residues, *(Hatfield, 1989).* The cell wall is a composite matrix with cellulose microfibrils embedded in an amorphous gel containing a relatively wide range of polysaccharides (*Hatfield, 1989). Shutte (1990), Annison (1990), Carre et al (1990)* and *Annison and Choct (1991)* refer to cereal cell wall polysaccharides (cellulose, hemicellulose, pectins, etc.) as non-starch polysaccharides (NSP).

Cereal structural polysaccharides vary in different species in monosaccharidic composition, substitution patterns, and glycosidic linkages between monomers *(Hatfield, 1989)*. Only structural characteristics of maize bran are discussed in detail in this review.

The pericarp and aleurone layers of maize kernels (figure 1) together with the germ make up what is known as maize bran *(Gohl, 1981; Sen et al., 1994)*. Arabinose and xylose, components of hemicellulose; and glucose, the monomer in cellulose; account for about 90% of the polysaccharidic constituents of maize bran *(Mongeau et al., 1991)*. The arabinose:xylose:glucose ratio approximate 0.83:1.5:1 *(Olson et al., 1983; Mongeau et al, 1991)*. Some crude protein is present as part of structural cell wall protein *(Mongeau et al., 1991)*. The oil content of maize bran is determined by the amount of germ in it. *Weber (1973)* reported that approximately 84% of the total oil in the maize kernel is in the germ . Thus, the higher the amount of germ in the bran the higher the oil content *(Weber, 1973)*. He further reported that the composition of this oil varies widely among varieties, with a low oil variety (K6) containing 74.9% triglycerides and a high oil variety (Illinois High Oil) containing 92.4 % triglycerides. Minor components include free fatty acids, waxes, phospholipids, pigments and odorous compounds *(Reiners and Gooding, 1970)* as well as glycolipids *(Weber, 1973)*.

Figure 1. Maize Kernel



From: Morphology and Growth of Maize by *Kling J G.*. IITA Crop Production Guide. 1991.

The cell wall polysaccharides of maize bran are esterified to phenolic acids in dimerization reactions *(Sen et al , 1994)*. Phenolic acids are primarily bound to hemicelluloses *(Kato and Nevins, 1985; Fincher and Stone, 1986)*. Phenolic acid cross-links in cell walls produce dimers such as diferulate or truxillic acid *(Eraso and Hartley, 1990)*. Phenolic acid amides including feruloyl- and diferuloylputrescine and related para-coumaric acid or spermidine analogues have been detected in maize bran *(Martin-Tanguay et al., 1982)*. The process of cross-linking in the cell wall polysaccharides makes tissues harder, limiting the biodegradability of the cell wall polysaccharides *(Hartley and Ford, 1989; Fry, 1983)*. The phenolic composition of maize bran includes flavonoids which are concentrated in the aleurone layer *(Martin-Tanguay et al., 1982)*.

Structural features common to other cereal brans are the presence of non-starch polysaccharides (NSP), the high concentration of phenolics *(Fulcher and Wong, 1980; Fulcher, 1982; Pussayanawin et al., 1988 and Irving, 1989; Sen et al 1994)*, the presence of phenolic acids and their amides *(Sen et al., 1994)*. There is, however diversity in the phenolic substances of cereals when conjugated or bound forms are considered *(Sen et al., 1994)*. Ferulic and para-coumaric acids (phenylpropanoid alcohols which make up true lignin) vary in proportion among generic plant sources *(Van Soest, 1982)*.

2.12 Digestibility of Dietary Fibre

Like other non-ruminants, birds do not possess the appropriate gastrointestinal (GIT) enzymes for NSP digestion *(Shutte, 1990)*. Fibre digestion in mammals is attributed to bacterial fermentation *(Shulze et al., 1994)*. The colon and caecum are the major sites of microbial colonization *(Clarke and Bauchop, 1977)* although ileal microbial digestion is also known. Experimental evidence suggests that a considerable part of NDF, probably the hemicellulose fraction, may be fermented in the small intestine of pigs *Graham et al., (1985), Longland et al., (1988),* and *Buraczewska et al. (1988). Shulze et al. (1994)* while working with pigs found that 20% of the ingested NDF was digested before the end of the ileum by microbial fermentation.

Because the colon of birds is much shorter than that of mammals, differences are expected between birds and mammals with regard to cell wall digestion *(Fonnesbeck et al., 1974)*. The microflora in the large intestine of birds seem to play a minor role, thus digestibility of NSP by

microbial fermentation is also low *(Shutte, 1990)*. The digestibility of cell wall polysaccharides from wheat (bran or whole grain) in cockerels and muscovy ducks *(Carre et al., 1990)* and rice bran in domestic fowls and ducklings *(Farrell, 1994)* were found to be low.

2.13 Chemical and Morphological Barriers to Degradation of Dietary Fibre

The architecture of the dietary fibre polymers (cellulose, pectins and hemicellulose) has an important impact on its fermentability *(Nyman et al., 1990; Bach Knudsen and Hansen, 1991)*. Dietary fibre containing primarily cellulose shows little in vitro fermentation by faecal microflora from humans and dogs *(Titgemeyer et al., 1991)* and is very slow in the rumen *(Beveridge and Richards, 1975; Hatfield, 1989)*. One of the restraints to cellulose degradation is said to be the extensive hydrogen bonding that occurs in the microfibrils *(Soltes, 1983)*. Dietary fibre high in uronic acid content is highly fermentable by human and dog faecal microflora *(Titgemeyer et al., 1991)* and rumen microorganisms *(Gaillard, 1962)*. The pectic fraction resistant to microbial degradation may represent a portion cross-linked by phenolics or covalently bound to lignin *(Hatfield, 1989)*. Degradation of xylans in cell wall matrices is incomplete *(Gordon et al., 1983)*. This has been attributed to close association and possible linkage to polyphenolic material *(Van Soest, 1981)*. Phenolics occur in high concentrations in most cereal brans *(Fulcher and Wong, 1980; Fulcher, 1982; Pussayanawin et al. 1988; Irving et al., 1989)* including maize bran *(Sen et al., 1994)*. Structural features of xylans also play a role in the extent of degradation. Xylans with a high degree of arabinose substitution (arabinose: xylose , 1:3 ratio) were degraded by hemicellulases isolated from the rumen to a lesser extent than less frequently substituted xylans *(Brice and Morrison, 1982)*. The arabinose : xylose : glucose ratio of approximately 0.83 : 1.5 : 1 in maize bran *(Olson et al., 1983; Mongeau et al., 1991)*, gives an arabinose : xylose ratio of about 1:1.8, further pointing to a low degradability of maize bran.

2.14 Effect of Dietary Fibre on Nutrient Digestibility

Addition of fibre to the diet can lead to a lower apparent ileal digestibility of starch, crude protein, fat and minerals in pigs *(Low, 1982; Graham et al., 1986; Fernandez and Jorgensen, 1986; Graham and Aman, 1987; Shulze et al, 1994)* and chicks *(Saito et al., 1959; Wagner and Thomas, 1977; Gohl et al., 1978; Day and Thomas, 1980; Nahm and Carlson, 1985)*. This can be as a result of changes in the rate of absorption of the different nutrients *(Vahony and Cassidy,*

1985; Low 1985; Rerat, 1985). Fibre may adsorb amino acids, peptides and minerals and withhold them from absorption *(Bergner et al., 1975; Sauer et al, 1991).* Anti-nutritive components of the fibre have been reported to be responsible for unfavourable effects on nutrient absorption.

Some anti-nutritive activity of cereal fibre has been attributed to the phytate (myoinositol hexaphosphate) content of the fibre. Cereals contain 0.7 to 2.0 per cent phytate, with maize having the least and rye the most *(Oberleas et al., 1966).* The phytates are said to be responsible for reducing the availability of some minerals *(Warren and Farrell, 1991)* and other components in the fibre *(Martin and Farrell, 1993).* Phytate may influence the availability of the macro-elements Ca, P and Mg as well as several trace elements by forming insoluble complexes with these nutrients *(Suttle, 1983).*

The cell wall polysaccharides or NSP of cereals also exhibit anti-nutritive activity when present in broiler diets *(Annison and Choct, 1991).* The anti-nutritive activity of NSP appears to be of greater significance in poultry diets than that of phytate. Anti-nutritive activity of NSP has been attributed to pentosans in several cereals and beta-glucans predominantly in barley *(Annison and Choct, 1991)* and oats *(Johansen et al., 1993).* Pentosans have been isolated from rye *(Preece and Mackenzie, 1952; Saini and Henry, 1989),* wheat *(Perlin, 1952; Fincher and Stone, 1974; MacArthur and D'Appolonia, 1980)* and triticale *(Saini and Henry, 1989),* a cross between wheat and rye. The growth of broilers was depressed and droppings were sticky when pentosans isolated from rye (mainly arabinoxylans) were added to experimental diets *(Antoniou and Marquardt, 1981; Ward and Marquardt, 1987; Fengler and Marquardt, 1988).* The effects of rye pentosans are said to be similar to those of other mucilaginous polysaccharides including pectins, guar gum, and gum arabic *(Vohra et al., 1979; Antoniou et al., 1981).* D-xylose and L-arabinose caused wet droppings when fed to chicks *(Shutte, 1990). Fengler and Marquardt (1988)* reporteded that water soluble pentosans are primarily responsible for the anti-nutritive activity of pentosans. *White et al. (1981)* noted a depression in growth of broilers when beta-glucans from barley were added to their diets.

The mechanism by which the pentosans exhibit anti-nutritive effects has been explained as being due to the highly viscous nature of these polysaccharides, which reduce the digesta passage time and impairs diffusion of digestive enzymes to their substrates and mixing with gut contents

(Antoniou et al., 1981; Antoniou and Marquardt, 1982). Viscous polysaccharides such as pentosans and beta glucans might also complex with digestive enzymes and reduce their activity *(Ikeda and Kusano, 1983).* Chick growth, feed utilization and the digestibilities of fat and amino acids were significantly depressed when rye pentosans were added to experimental diets *(Antoniou et al., 1981).* Wheat pentosans caused a general inhibition of nutrient digestion affecting starch, fat and protein, indicating that they act in the same manner as the anti nutritive NSP of rye and barley *(Annison and Choct, 1991).*

There is evidence that the anti-nutritive effect of NSP is mediated by the gut microflora as dietary supplementation with antibiotics partially improves the nutritive value of rye *(MacAuliffe and McGinnis, 1971).* The addition of procaine penicillin to rye-based diets resulted in marked increases in chick growth and efficiency of feed utilisation *(Moran et al., 1969; MacAuliffe and McGinnis, 1971)* as well as feed intake and the retention of all nutrients *(Misir and Marquardt, 1978).* Antibiotic induced improvement is related to the NSP content in the cereal *(Annison and Choct, 1991).* The improvement may be the result of inhibition and suppression of intestinal microflora which compete with the host for available nutrients *(Misir and Marquardt, 1978).* Deconjugation of bile salts *(Campbell et al., 1983; Feighner and Dashkevicz, 1988)* and the production of toxins are also possible effects of deleterious microorganisms *(Annison and Choct, 1991).* They further postulated that when diets with high NSP content are ingested, a part of the polysaccharides may dissolve in the upper gut of chickens and move down to the lower gut where it becomes a fermentable carbohydrate source enabling the hindgut anaerobes to proliferate in a manner detrimental to the bird. The water soluble portion of NSP is extensively degraded in the intestinal tract of birds *(Carre et al., 1989; Carre and Leclerq, 1985). Carre et al., (1989)* found that the water insoluble NSP remained almost undegraded by cockerels and ducks. The fact that domestic birds are devoid of cellulolytic activity *(McNab, 1973)* would explain why the birds are unable to digest water-insoluble cell wall materials *(Carre et al., 1989).*

Barley and wheat contain higher levels of NSP than maize *(Choct and Annison, 1990).* The performance of chicks on rye diets is inferior to that of chicks fed comparable wheat diets *(Antoniou and Marquardt, 1982).* Water treatment removes the water soluble pentosans and glucans by activating endogenous enzymes capable of degrading these polysaccharides. The degree of improvement in growth, feed utilisation, retention of protein and the digestibilities of

amino acids and fat depends on the concentration of the water soluble NSP in the cereal *(Annison and Choct, 1991). Adams and Nabler (1969)* reported that the response to water treatment was consistently high for barley and wheat, only occasional responses were seen with maize. This could mean that maize has a lower water-soluble NSP content than other cereals.

Mongeau et al., (1991) while working with rats observed that maize bran was the most resistant to microbial degradation (7% degraded) compared to Hard Red Spring wheat bran which was partially degraded (31%) and oat bran which was most degraded (76%). Most of the maize bran pericarp tissue remained structurally intact, as evidenced by the emission of intense autofluorescence under UV light of the phenolic constituents, *p*-coumaric acid and ferulic acid. In human subjects, practically all of the NDF of the corn bran ingested was recovered in faeces and appeared unchanged under electron microscopy, while wheat bran NDF was substantially degraded *(Dintzis et al., 1979)*. McBurney (1990) reported NDF fermentations of 39% for wheat bran, 6.9% for corn bran, and 78.1% for oat bran when they were fermented *in vitro* in human fecal inoculum. These observations may have some significance to the level of anti-nutritive activity of the brans with maize bran having the lowest anti-nutritive activity.

2.15 Effects of Dietary Fibre on GIT Morphology

Sauer and Ozimek (1986), Low (1989) and Graham and Aman (1991) indicated that addition of fibre to non-ruminant diets induced varying physiological responses depending on the level and source of the fibre. Weight, volume and capacity of the GIT have been shown to increase with increasing dietary fibre in pigs and rats *(Coey and Robinson, 1954; Southgate, 1990; Hansen et al., 1992; Jin, 1992)*. Addition of cellulose to low fibre diets induced a significant increase in colonic DNA synthesis in rats *(Sircar et al., 1983; Jacobs and Lupton, 1984)*.

It has been reported that endogenous secretions, including pancreatic juice *(Ikegami et al, 1990)*, bile *(Portman et al, 1985)*, mucus *(Low, 1989)*, and sloughed epithelial cells are expelled in larger amounts when experimental non-ruminant animals are fed purified diets supplemented with fibre.

2.16 Beneficial Metabolic Effects of Maize Bran

Hemicellulose fractions obtained from cereals such as from wheat bran and maize bran, have physiological functions *(Ohta et al., 1994)*. Refined maize bran has hepatoprotective activities against the hepatic injury caused by galactosamine *(Ayano, 1992)*, orotic acid *(Miyasaka et al., 1992)*, and ethanol *(Ebihara et al., 1992)*. *Ohta et al. (1994)* also found that low molecular and high molecular fragments of maize bran hemicellulose have antioxidative activities in peroxidative systems.

Phenolic acids such as ferulic and *p*-coumaric acids are known to be naturally occurring antioxidants *(Cuvelier et al., 1992; Onyeneho and Hettiatachchy, 1992)* in the Gramineae cell wall. Phenolic compounds are concentrated in the aleurone and bran portions of cereal kernels *(Pussayanawin and Wetzel, 1987)*. In maize, they are concentrated in the pericarp, aleurone layer and germ, where ferulic acid is by far the most abundant phenolic *(Sen et al., 1994)* substance. Flavonoids, also located in the pericarp, aleurone layer and germ of the maize kernel *(Sen et al., 1994)* , have attracted interest as potential natural antioxidants both for inhibiting oxidative deterioration of foodstuffs and for providing beneficial metabolic effects in animals *(Herrmann, 1976; Kuhnau, 1976; Singleton, 1981; Fahey and Jung, 1989)*. Apart from antioxidant properties, other beneficial effects of flavonoids in animal metabolism appear to be related to their chelating properties *(Fahey and Jung, 1989)*. Flavonoids have been indicated in protective effects against hepatoxic agents *(Fraga et al, 1987)*, lipid peroxidation in human platelets *(Koch and Loffler, 1985)* and reduction of capillary fragility and permeability problems in humans *(Fahey and Jung, 1989)*.

2.17 Levels of Cereal Bran in Chicken Diets

Rice bran can be successfully included in the diet of broiler chickens up to 200 g/kg feed. Laying birds can tolerate up to 450 g/kg rice bran in their diet *(Farrell, 1994)*. He also found that digestibility of amino acids in rice bran is lower for young chickens than adult birds.

Rice hulls have been used to reduce the energy content of diets for replacement pullets and broiler breeder males and hens. Recommended maximum inclusion levels of rice hulls is 150 g/kg for broiler breeders and 50 g/kg diet for growing pullets above 8 weeks of age *(Farrell, 1994)*.

The above information indicates that tolerance of dietary fibre increases with age of the birds. *Annison and Choct (1991)* observed that the apparent tolerance of NSP by older birds may be due to the presence of a more developed or stable microflora. According to *Humbert et al (1989)*, the number of adhering bacteria increases with the age of the chick and the morphological and quantitative changes of the caecal microflora are completed by 15 days of age.

2.2 METHODS OF DETERMINING NUTRIENT AVAILABILITY IN BROILER DIETS

The foregoing review on dietary fibre in poultry diets gives indications that maize bran may be regarded as a fibre source with comparably low anti-nutritive effects in poultry diets. Maize bran may also alter available nutrient density of the diet. The need arises therefore, to determine the extent of adequacy or inadequacy of the maize bran containing diets in meeting broiler requirements for growth. Various methods of assessing nutrient availability in diets or single ingredients have been developed. They range from chemical or *in vitro* methods to digestibility and growth assays (*Austic, 1983)*. The growth assay method will be reviewed as pertaining to protein, energy, calcium and phosphorous adequacy in broiler diets. The four nutrients are the ones expected to be affected by addition of maize bran to broiler diets. The digestibility method has also been reviewed.

2.21 Growth Assays

The growth assay method of determinimg nutrient availability in a diet is based on animal performance, with the measure of performance being weight gain *(Austic, 1983; Church and Pond, 1988). De Muelenaere et al. (1967)* reported that the nature of the diet affected the size of the GIT in rat growth assays. For this reason they suggested that empty body weight is a better measure of response than total body weight. The use of total or empty body weight is based on the assumption that body or carcase composition is constant *(Austic, 1983)*. Other useful performance parameters measured in growth assays are feed consumption and feed efficiency. Feed efficiency is derived from weight gain and feed consumption data. Feed efficiency is the unit of weight gain per unit of feed consumed. Feed conversion ratio (FCR) is an inverse

presentation of feed efficiency. It is computed as the amount of feed required per unit of weight gain. Diets that promote a high rate of gain will usually result in a greater efficiency than diets that do not allow such rapid gain *(Church and Pond, 1988).*

In this experiment performance parameters that were measured are total live body weight, referred to as simply liveweight; feed consumption and feed conversion ratio (FCR).

2.211 Dietary protein influence on performance

Factors such as dietary protein levels and amino acid balance can influence growth assay results *(Austic, 1983).* There is no evidence of a metabolic requirement for dietary protein per se, but only for amino acids. The quantitative protein requirement is greater for growth than for maintenance and is affected by sex (males tend to have a higher requirement) and by species, and probably by genetic make up within species. Signs of protein deficiency include, among others, reduced growth rate and reduced efficiency of feed utilisation *(Church and Pond, 1988).*

The dietary balance of amino acids has a marked influence on amino acid utilisation *(Grau and Kamei, 1950; Harper et al., 1970; Austic 1983).* Amino acid imbalances are nutritional conditions in which the presence of some amino acids in the diet in excess of the requirement increase the requirement of the first limiting amino acid *(Harper et al., 1970, Austic 1983).* .

Antagonisms are another category of nutritional interactions in which excesses of individual or groups of amino acids increase the requirement of other amino acids *(Harper et al., 1970).* In an antagonism the growth depression caused by a single amino acid may be reversed by a structurally related amino acid *(Scott et al., 1982).* Excesses of leucine may be severely growth depressing unless additional isoleucine and valine are added to the diet. Similarly, excesses of isoleucine and valine can cause a growth depression which may be alleviated by more leucine *(Rogers et al., 1967).* The antagonism between lysine and arginine appears to be a particularly important one in birds. Excesses of lysine markedly increase the arginine requirements of chicks *(Jones, 1964; Boorman and Fisher, 1966; Smith and Lewis, 1966; Nesheim, 1968).* Excess arginine has less effect on lysine requirement except at rather deficient levels of lysine. Lysine accumulates at very high levels in plasma and tissue fluids, probably because it is rather slowly metabolised *(Austic and Nesheim, 1970).* Arginine does not accumulate to this extent and seems to be readily degraded by chicks. Arginase activity is readily altered under varying dietary

conditions. Arginase activity is increased by conditions involving excesses of lysine, valine or leucine *(Eliasson and Strecker, 1966)*, isoleucine, tyrosine, histidine and phenylalanine *(Snetsinger and Scott, 1961; Nesheim, 1968; Smith, 1968).*

Some amino acids seem to be outright toxic when fed at high levels. This toxicity may be partially alleviated by other amino acids but not completely. Methionine is particularly growth depressing at high levels *(Harper et al, 1970).* Tyrosine, phenylalanine, tryptophan and histidine are also toxic, but levels as high as 2-4 % of the diet may be required to produce the toxic effects. Glycine can be toxic to chicks if the diet is deficient in niacin or folic acid. Provided these essential co-factors for glycine metabolism are present, chicks can tolerate large amounts of glycine *(Scott et al., 1982)*.

In this experiment the amino acid imbalances, antagonisms and toxicities are worth noting due to the use of synthetic methionine and lysine in the experimental broiler diets which if not properly used may give signs of protein deficiency. This may affect interpretation of data on effect of different levels of maize bran on growth, feed consumption and feed efficiency.

2.212 Dietary energy influence on performance

Chickens tend to increase feed consumption as the energy content of the diet is reduced *(Scott et al. 1982). Scott et al. (1942)* demonstrated that chick diets which were high in energy promoted more rapid growth and more efficient feed conversion than did chick diets which contained relatively lower levels of energy. *Scott et al. (1982)* indicated that as the energy content of the diet is reduced, growth is reduced and the amount of fat deposited in the carcass is decreased. As long as the energy content of the diet is adequate for maintenance, no other deficiency symptoms are observed. They also explained that when the energy content of the diet is grossly excessive, feed consumption is so curtailed that severe deficiencies of protein, amino acids, minerals and vitamins occur; growth may cease entirely; the chickens may become very fat but at the same time show signs of protein and vitamin starvation. There is considerable evidence to show that the Calorie: Protein ratio in the diet exerts a profound influence upon the growth rate, feed consumption, feed efficiency, body composition and feathering of poultry *(Berg and Bearse, 1958; Berg, 1959; Leong et al.,1959; Donaldson et al., 1956; Sunde, 1956; Vondell and Ringrose, 1958; Sibbald et al 1961).* *Scott et al. (1948)* reported that as the protein level of a chick diet was increased, it was necessary to increase the dietary energy level

and the unidentified vitamin content of the diet if the most rapid growth and the most efficient feed conversion were to be obtained. Higher Calorie: Protein ratios tend to support a greater deposition of fat *(Sibbald,et al; 1961).* Diets with small energy: protein ratios promote lean broiler carcasses *(Donaldson et al., 1956; Thomas and Combs, 1967).*

2.213 Dietary calcium and phosphorous influence on performance

Wilgus (1931) showed that diets must contain not only minimum levels but also an optimum ratio of calcium to phosphorus. He was the first to establish the quantitative limits for calcium and phosphorus for normal bone formation in chicks. He reported that the minimum available phosphorus requirement was approximately 0.5% and that the calcium: phosphorus ratios needed for normal growth in chicks varied between 1.0: 1 and 2.2: 1.

Symptoms of calcium deficiency include, among others, retardation of growth, decreased feed consumption and osteoporosis or low calcium rickets (*Scott et al; 1982).* A reduction in growth of broiler chickens caused by high dietary calcium (12 –14 g Ca /kg) was reported by *Smith and Taylor (1961). Smith and Kabaija (1985)* and *Hussein et al. (1986*) reported that diets containing, respectively, 17, 18 and 30 g Ca / kg did not significantly affect weight gain. *Shafey and McDonald (1990)* noted that while there is substantial agreement in literature that high Ca intake depresses poultry performance, there is some disagreement concerning the maximum tolerated level of Ca.

A deficiency of phosphorus or a wide upset in the Ca: P ratio of the diet causes rickets and growth failure. Severe deficiency or lack of availability of phosphorus in the diet results in early loss of appetite, weakness and death within a period of 10 to 12 days *(Scott et al., 1982).*

2.22 Determination of Digestibility of Nutrients

Scott et al. (1982) explained measurement of digestibility as an attempt to determine the amount of a given nutrient absorbed in the gastrointestinal tract from a given quantity of food. They indicated that measurement of digestibility involves both the process of digestion i.e., hydrolysis to release the nutrients in a form in which they can be absorbed, from the intestinal lumen.

According to *Scott et al. (1982)* digestibility can be measured by accurately measuring feed intake and faecal output. From these measurements, together with chemical analysis for the nutrient content of the feed and faeces composition, the digestibility is then calculated as:

$$\frac{\text{Dry weight of diet eaten} \times \text{\% Nutrient in diet} - \text{Dry weight of faeces voided} \times \text{\% Nutrient in faeces}}{\text{Dry weight of diet eaten} \times \text{\% Nutrient in diet}} \times 100$$

This procedure is used in the experiment to determine the digestibility of dry matter, crude protein, lipids (as Ether Extract), energy (as Metabolisable Energy), neutral detergent fibre, Calcium and Phosphorous as Apparent Digestibility coefficients since the data from which it is obtained is uncorrected for endogenous losses (e.g., losses of protein in faeces of animals receiving a protein- free diet) *(Scott et al., 1982).*

Scott et al. (1982) note that since urine and faeces are voided together in chickens, it is difficult to establish the origin of the components of the excreta.

2.3 PERFORMANCE CHARACTERISTICS OF STRAINS USED IN THE EXPERIMENT

2.31 Arbor Acres.

Performance information on the arbor acres strain of broilers are available in the *Arbor Acres Update* supplied to the customer by the hatchery.

Table 2.1: ARBOR ACRES BROILER PERFORMANCE CHARACTERISTICS

Age (Weeks)	Body Weight (g)	Cumulative Feed Consumption (g)	Feed Conversion Ratio
1	165	144	0.87
2	405	441	1.09
3	735	926	1.26
4	1150	1633	1.42
5	1625	2568	1.58
6	2145	3754	1.75
7	2675	5136	1.92
8	3215	6784	2.11

Source: Hybrid Poultry pamphlet: *Arbor acres Update* (not dated)

2.32 Cobb 500 Performance Characteristics

The Cobb broiler performance information is obtained from the 1993 Cobb 500 Product Profile provided to the customer. The information is presented as performance targets, based on achievements by producers around the world.

Table 2.2 COBB 500 BROILER PERFORMANCE CHARACTERISTICS

Age (Weeks)	Body Weight (g)	Cumulative Feed Consumption (g)	Feed Conversion Ratio
0	42	0	0.00
1	190	171	0.90
2	444	532	1.20
3	800	1094	1.37
4	1234	1858	1.51
5	1700	2799	1.65
6	2178	3917	1.80
7	2668	5202	1.95
8	3159	6642	2.10

Source: *Cobb 500 Product Profile (1993)*

CHAPTER III

3.0 MATERIALS AND METHODS.

Arbor acres chicks (initially 465 birds) provided by Hybrid Poultry Farm of Chamba Valley in Lusaka, and Cobb chicks (initially 450 birds) provided by Caledonian Hatcheries of Makeni in Lusaka, were reared simultaneously, but in separate pens from 19th April to 20th June, 1999 in a poultry house at the University of Zambia Animal Science Department Field Station. Both Arbor acres and Cobb broilers are hybrid strains. After a brooding period of 26 days, the birds were placed in experimental pens where they were fed experimental diets. Chemical analyses were done to assess levels of nutrients in the feed ingredients, feed formulations and faeces from digestibility trials. Histological analyses were done to observe effects of the maize bran containing diets on the lower parts of the gastrointestinal tract.

3.1 HOUSING

The poultry house had an east-west orientation with windows on the northern and southern wall and the only door in the middle of the western wall. The rough concrete floor of the building covered an area 21 m x 8.4 m. The longer northern and southern walls rose 2.3 m from the ground while the middle of the roof rose about 3 m from the floor. The roof was made of corrugated iron sheets. The first 3.1 m of floor space from the door were taken up by two store rooms. The rest of the building was open and was used for rearing the experimental birds.

The rearing area had five windows on each of the northern and southern walls. Four of the windows on each side measured 4 m x 0.95 m and the smaller window measured 0.80 m x 0.95 m. The windows were covered with wire gauze having 1 inch diameter holes. Approximately 20 cm of the same wire gauze separated the roof from the rest of the wall.

3.11 Pre-rearing History and Preparation of thePoultry House

The house had been dormant for over three years. It was selected for the experiment because it was the largest building that was in good enough condition to accommodate 42 approximately 1 m x 2 m experimental units. Three weeks before the chicks arrived, the rearing area of the poultry house was cleaned and disinfected with microl. A week later the windows were covered with black polythene sheets to keep wind draughts out as well as assist in regulating temperatures inside the building during the rearing period. Three days before the chicks arrived

a brooding area was demarcated at the far end of the building from the entrance using 1 m x 1 m and 1 m x 2 m wood and wire mesh experimental unit dividers. The holes in the mesh were approximately 1 inch in diameter. The brooding area was about 8.4 m x 4.4 m (36.94 sq.m). This area was divided into two using other experimental dividers to leave a 50 cm passage between the two pens. This was done to ensure complete separation of the chicks belonging to the two strains. A 6 cm layer of National Milling maize bran was placed on the floor as litter. A black polythene sheet was hung to divide the brooding area from the rest of the rearing area and to assist in regulation of air and heat movement between the two areas.

3.2 EXPERIMENTAL DESIGN, TREATMENTS AND UNITS

3.21 Experimental Design

The feeding trials were carried out in a 3 factor (2 strains x 2 starting dates for bran feeding x 4 bran levels) Randomised Complete Block Design. There were 3 replicates for each treatment. The number of replicates was a balance between the smallest number acceptable for good statistical analysis and the largest number affordable with the limited research funds.

Factors considered when making the blocks were:

i) distance from the door, which would affect the level of attention and disturbance that the birds in the different blocks would be subjected to. The birds nearest the door were expected to receive the best attention as well as the most disturbance.

ii) initial number of birds per experimental unit, with the first 2 blocks having 21 birds in each unit and the remainder distributed in experimental units in the last block.

iii) condition or size of feeders, with the last block having the worst feeders in terms of feed wastage.

Block I was nearest the entrance to the building, followed by Block II and then Block III. The treatments were assigned to the experimental units using *Little and Hills (1978)* random numbers.

3.22 Treatments

Treatments were applied to some of the experimental birds from 29 days of age and to others from 35 days of age. 4 experimental diets were made to contain 0 g, 100 g, 200 g and 300 g of maize bran respectively, per kilogram of finisher feed. Seven treatments were applied to each of the two strains to make a total of 14 treatments as in table 3.1. To reduce on costs, treatments A/0/29 and C/0/29 served as controls for both the 29th and 35th days of starting to feed diets containing bran . It was assumed that there would be negligible variation in results if control treatments were set up specifically for the 35th day feeding date.

Table 3.1 TREATMENTS

No.	STRAIN	STARTING AGE (Days)	BRAN LEVEL (%)	TREATMENT CODE
1.	Arbor Acres	29	0	A/0/29
2.	"	29	10	A/10/29
3.	"	29	20	A/20/29
4.	"	29	30	A/30/29
5.	"	35	10	A/10/35
6.	"	35	20	A/20/35
7.	"	35	30	A/30/35
8.	Cobb 500	29	0	C/0/29
9.	"	29	10	C/10/29
10.	"	29	20	C/20/29
11.	"	29	30	C/30/29
12.	"	35	10	C/10/35
13.	"	35	20	C/20/35
14.	"	35	30	C/30/35

3.23 Experimental Units

Arbor acres and Cobb broilers were placed in experimental units of 20 to 24 birds each. Each treatment had 3 replicates so that there were 21 experimental units having Arbor acres birds and 21 units having Cobb birds. This made a total of 42 experimental units. Twenty birds per experimental unit was decided upon as a minimum in order to ensure reliability of the results in view of possible genetic variability among the individual birds.

3.3 BIRD MANAGEMENT

3.31 Brooding

The day old chicks were collected from their respective hatcheries on the morning of 19th April, 1999, starting with Arbor acres chicks. Placing of the chicks into the brooding pens was done at the same time and was completed within an hour and a half, from the first 10 Arbor acres chicks to be removed from their box and weighed to the last 10 Cobb chicks to be released. The brooding pens already had pre-starter feed on newspapers and in chick feeders (8 in each pen) hanging from the roof. Water was also already in place, provided in two 4.5 litre drinkers in each pen.

Artificial heat was not provided during the first day because of the high day temperatures. The distribution of the chicks was even and there was no sign of abnormal behaviour such as bunching or concentrating in one area of the pens. On the first night the circular heater (1.2 m in diameter), which was hung centrally in position between the brooding pens developed a fault which could not be corrected because the switchboard where power could be turned off was for that night inaccessible. The fault was corrected first thing on the second day. Thereafter, artificial heat was provided at night until the 24th night and was provided during the day on the basis of chick distribution. No thermometer was used to monitor pen temperatures. Plastic sheets over the windows were lifted appropriately to regulate temperature or ventilation.

An attendant was available on the first 3 nights to monitor distribution of the chicks to avoid suffocation due to over-bunching which is a major cause of death in chicks at this time. On the 8th day the researcher while in custody of the keys to the poultry house was involved in, but

survived an early morning tragic road traffic accident. On this day access was only gained to the poultry house after 14:00 hours. The chicks were consequently subjected to heat, water and nutritional stress, including lack of ventilation.

Pre-starter feed (24 % crude protein) was fed to the chicks up to the 13th day when starter feed (22 % crude protein) was fed up to the 26th day. Feed was weighed before being placed in feeders. The number of drinkers was increased to meet demand until there were 7 drinkers in the cobb pen and 10 drinkers in the arbor acres pen. Amprolium was given in the drinking water up to the 10th day and tetravit up to the 13th day. The coccidiostat and the antibiotic-vitamin-mineral premix were administered to reduce the possibilities of disease outbreak and cross infections since birds from two different hatcheries and of different genetic make up were being reared together. RX 184 vitamin- mineral premix was given in water from the 14th to the 21st day to ensure good growth rates.

Gumboro vaccine was administered in water on the 15th day and Newcastle (La sota) on the 22nd day.

The birds were moved to their experimental pens on the 24th and 25th days. Birds in Block I and part of Block II were moved on day 24 and the rest on day 25. Birds were randomly selected from the brooding pens for placement in the experimental pens.

3.32 Growing/Finishing Management

The birds were confined in their experimental pens using wood and wire mesh experimental unit dividers. 1 m x 1 m dividers were used to make the aisle end of the pens while 1 m x 2 m dividers made the separating walls between pens. The length of the rearing area of the poultry house (approximately 18 m) accommodated 21 pens on each side of the aisle, each pen measuring 0.8-0.9 m x 2 m. This gave a stocking rate of 12-15 birds per square metre. All pens had approximately 5 cm of fresh maize bran placed on the floor as litter.

Each pen had a 4.5 litre drinker and an adult-bird tubular feeder. Weighed feed was placed in feeders. Over filling of feeders was avoided. Feed levels were checked every day and topped up where necessary to about half the full capacity of the feeders, with weighed feed. On the 26th and 27th days all birds were fed ordinary finisher diet in preparation for the treatment diets. From the 29th day feed type depended on the experimental diet assigned to each unit.

Black plastic sheets were placed over the windows at night to protect birds from night chills as birds would be huddled up in the morning and inactive until the building became warmer. This practice was terminated on day 37 when ascites was diagnosed in a dead Arbor acres bird (Section 4.4).

3.33 Digestibility Trials

On the 54th day 6 birds were randomly selected from those of each strain feeding on the four experimental finisher diets. These birds were placed in eight 1 m x 1 m cages having a 1 inch wire mesh floor. Birds of the same strain and treatment but from different replicates were placed in the same cage.

Each cage had a 4.5 litre drinker and a feeder. The birds were collectively fed 500 g meals of their respective treatment diets for 3 consecutive days. All the feed was consumed on the same day. The floor under the wire mesh was swept daily. Faeces were collected on the 3rd and 4th days and dried in an oven at 105 ^{0}C for 24 hours before being packed in labeled plastics. The faeces were used to determine the digestibility of different nutrients in the experimental diets.

3.4 FEED INGREDIENTS, COSTS OF INGREDIENTS, FEED FORMULATIONS

Three basic formulations were fed to the experimental birds. A pre-starter formulation having 24% crude protein was fed for the first 13 days. Thereafter, a starter formulation containing 22% crude protein was fed up to the 26th day. The finisher formulation (19% crude protein), fed to the end of the experiment, was modified with different levels of maize bran to suit experimental diet specifications.

3.41 Feed Ingredients and Costs of Ingredients

Feed ingredients were purchased from wherever they were available within Lusaka, usually from the cheapest source. Table 3.2 gives a list of feed ingredients used in the formulations, sources and costs. Nutrient content of feed ingredients is contained in Appendix A i).

Table 3.2: FEED INGREDIENTS, SOURCES AND COSTS

No.	INGREDIENT	SOURCE	COST (K)
1.	Maize	Soweto Market	23,000 per 50 kg bag
2.	Soyabean Meal	Livestock Coop. S. Services	32,000 per 50 kg bag
3.	Cooking oil (Amanita)	Wholesale shop	68,000 per 20 litres
4.	Dicalcium Phosphate	Livestock Coop. S. Services	47,000 per 50 kg bag
5.	Limestone Meal	Mindeco Small Mining Ltd.	3,500 per 50 kg bag
6.	Broiler Premix	Livestock Coop. S. Services	32,000 per 3 kg pack
7.	Salt	"	16,000 per 50 kg bag
8.	Lysine	"	8,000 per kg pack
9.	Methionine	"	13,000 per kg pack
10.	Maize Bran	A.P.G. Milling Company	2,500 per 20 kg
11.	Maize Bran	National Milling Company	4,200 per 30 kg

3.42 Feed Formulations

3.421 Pre-starter formulation

Scott et al. (1982) recommended that for broiler chicks aged 0-2 weeks a diet containing 24.0% crude protein should have an energy content of 2900 K cal/kg. Ensminger et al. (1990) recommended 3200 K cal /kg energy for 23.0% crude protein content for chicks of the same age. Table 3.31 gives a summary of nutrients supplied by feed ingredients used in the pre-starter formulation and quantities of ingredients used to produce approximately 100 kg of formulation.

Table 3.31 SUMMARY OF NUTRIENTS SUPPLIED BY FEED INGREDIENTS IN PRE-STARTER FORMULATION

INGREDIENT	%	NUTRIENTS SUPPLIED[a]					
		CP %	ME (K cal.)	LYS %	MET %	Ca %	P %
Maize Meal	46.0	3.0	1518	0.10	0.05	-	-
Cooking Oil	3.8	-	327	-	-	-	-
Soyabean Meal	45.5	20.7	1091	1.05	0.21	0.36	0.09
Dicalcium Phos.	2.36	-	-	-	-	0.31	0.36
Limestone Meal	1.00	-	-	-	-	0.32	-
Lysine	1.20	-	-	0.05	-	-	-
Methionine	0.50	-	-	-	0.24	-	-
Salt	0.30	-	-	-	-	-	-
Broiler Premix	0.50	-	-	-	-	-	-
TOTALS	101.16	23.7	2936	1.20	0.50	0.99	0.45
REQUIREMENT	100	24.0	3200	1.20	0.50	1.00	0.45
DIFFERENCE	+1.16	-0.3	-264	0.00	0.00	-0.01	0.00

[a] CP Crude protein
ME Metabolizable energy
Lys Lysine
Met Methionine
Ca Calcium
P Phosphorus

3.422 Starter formulation

Scott et al. (1982) recommended a diet containing 22% crude protein for broiler chicks aged 3 to 6 weeks, with a corresponding energy content of 3,200 K cal/kg. Ensminger et al. (1990) recommended an energy level of 3,300 K cal/kg for a 22% crude protein containing diet. Table 3.4 is a summary of nutrients supplied by feed ingredients used and amounts of ingredients used to produce approximately 100 kg of the starter formulation.

Table 3.32 SUMMARY OF NUTRIENTS SUPPLIED BY FEED INGREDIENTS IN STARTER FORMULATION

INGREDIENT	%	NUTRIENTS SUPPLIED[a]					
		CP %	ME (K cal.)	LYS %	MET %	Ca %	P %
Maize Meal	51.0	3.34	1683	0.10	0.05	-	-
Cooking Oil	3.8	-	327	-	-	-	-
Soyabean Meal	40.5	18.49	972	0.93	0.20	0.32	0.08
Dicalcium Phos.	2.6	-	-	-	-	0.34	0.37
Limestone Meal	0.96	-	-	-	-	0.31	-
Lysine	0.17	-	-	0.17	-	-	-
Methionine	0.25	-	-	-	0.25	-	-
Salt	0.30	-	-	-	-	-	-
Broiler Premix	0.50	-	-	-	-	-	-
TOTALS	100.08	21.83	2982	1.20	0.50	0.97	0.45
REQUIREMENT	100	22.00	3200	1.20	0.50	1.00	0.45
DIFFERENCE	+0.08	-0.17	-218	0.00	0.00	-0.03	0.00

[a] CP Crude protein
ME Metabolizable energy
Lys Lysine
Met Methionine
Ca Calcium
P Phosphorus

3.423 Finisher formulations

Scott et al. (1982) recommended a broiler finisher diet having 19% crude protein and corresponding energy content of 3000 to 3100 K cal/kg. Ensminger et al. (1990) recommended an energy level of 3,200 Kcal/kg for 19% crude protein content in a diet for finishing broilers. Table 3.33 is a summary of nutrients supplied by feed ingredients used and amounts of ingredients used to produce approximately 100 kg of the basal finisher formulation.

Table 3.33 SUMMARY OF NUTRIENTS SUPPLIED BY FEED INGREDIENTS IN BASAL FINISHER FORMULATION

INGREDIENT	%	NUTRIENTS SUPPLIED[a]					
		ME (K cal.)	CP %	LYS %	MET %	Ca %	P %
Maize Meal	68.5	2261	5.99	0.14	0.07	-	-
Soyabean Meal	27.0	648	13.12	0.62	0.12	0.22	0.05
Dicalcium Phosp.	2.28	-	-	-	-	0.30	0.35
Limestone Meal	1.17	-	-	-	-	0.38	-
Lysine	0.24	-	-	0.24	-	-	-
Methionine	0.19	-	-	-	0.19	-	-
Salt	0.30	-	-	-	-	-	-
Broiler Premix	0.50	-	-	-	-	-	-
TOTALS	100.18	2909	19.11	1.00	0.38	0.90	0.40
REQUIREMENT	100	3200	19.00	1.00	0.38	0.90	0.40
DIFFERENCE	+0.18	-291	+0.11	0.00	0.00	0.00	0.00

[a] CP Crude protein
ME Metabolizable energy
Lys Lysine
Met Methionine
Ca Calcium
P Phosphorus

3.424 Composition of treatment formulations

Maize bran was added to the Basal Finisher Formulation to make treatment diets in 100 kg quantities as in Table 3.34. Nutrient content of treatment formulations (Appendix A ii)

Table 3.34 COMPOSITION OF TREATMENT FORMULATIONS

DIET No.	FINISHER kg	BRAN LEVEL (kg)	BRAN LEVEL (%)
1.	100	0	0
2.	90	10	10
3.	80	20	20
4.	70	30	30

3.43 Feed mixing

A Turning and Metals hammer mill (Turning and Metals Company, Lusaka, Zambia) was used to reduce the maize and soyabean meal particle size. A 3 mm sieve was used for maize meal and an 8 mm sieve was used for soyabean meal. Bags of maize meal, soyabean meal and maize bran were weighed on a 150 kg capacity Gascoigne animal weighing scale. A 3.1 kg capacity Kern KK (Kern and Sohn Company, Albstadt-Ebingen, Germany) laboratory electronic balance was used to weigh the required quantities of dicalcium phosphate, limestone meal, broiler premix, methionine, lysine and salt. A Marion Mixer (Model 2030, Rapids Machinery Company, Marion IOWA, USA) with a capacity of 250 kg was used for mixing the different formulations in 100 kg and 200 kg quantities.

3.5 DATA COLLECTED

3.51 Liveweight

Every first and fifth day of the week the birds were weighed.

< All day old chicks were weighed in batches of 10 and mean weight for the strain was determined by adding up the batch weights for each strain and dividing the total weight with the total number of chicks in the strain.

- In the first 4 weeks birds were weighed in batches of 5 and mean weight for the respective strains determined by dividing total weight by total number of birds in each strain.
- From the 5th to the 7th week all birds in the specific experimental pens or units were weighed in batches of 5 and the mean weight for each unit determined by dividing the total weight for the unit by the number of birds in the unit.

3.52 Feed Consumption

The weight of feed placed in the feeders was recorded and mean daily feed consumption per bird, and mean total feed consumption per bird up to the 43rd and 47th days determined.

3.53 Mortality Rate

Mortalities were recorded on a daily basis. The number of dead birds and possible causes of death for each day, for each strain were recorded up to the 26th day. Thereafter, the number of dead birds and possible causes of death for each experimental unit, for each day were recorded.

3.54 Variable Costs and Revenue

- Finisher feed costs were determined by multiplying mean feed consumption per bird (in kg) by cost per kg of treatment formulations for each experimental unit. Finisher feed costs were determined for up to the 43rd and 47th days.
- Total feed costs were determined by multiplying cost per kilogram for pre-starter and starter feeds by mean feed consumption per bird (in kg), respectively and adding to finisher feed costs for up to the 43rd and 47th days.
- Total variable costs were determined by adding cost of feed, labour, transport, litter, and veterinary expenses per bird up to the 42nd and 47th days. There were no cost incurred on electricity, water and heating.
- Revenue per bird was determined through information on prevailing market prices in the period June to August, 1999 for live birds. These were assumed to be prices at which a small broiler producer (100 to 300 bird production) would be able to sell the birds.

The revenue and variable costs per bird were used in the calculation of gross margin returns for the different treatments.

3.55 Carcass Characteristics

On the 48th day, 5 birds from each experimental unit were randomly selected for examination of carcass characteristics, to measure in terms of weight the effect of different levels of maize bran on these characteristics. The birds had been starved for at least 24 hours. Birds from the same unit were weighed in one batch and mean liveweight for each of the 42 samples of birds determined. The birds were slaughtered and feathers removed.

< Mean dressed carcass weight was determined by weighing individual carcasses after head, neck, feet and viscera were removed. The total weights of the carcasses for the experimental unit sample was then divided by 5 (number of birds in the sample)

< Mean dressing out percentage was determined by dividing mean carcass weight for the experimental unit sample by the mean liveweight for the sample of birds and then multiplying by 100.

< Mean weights for the different sections of the gastrointestinal tract were determined by weighing them in sample batches and then dividing by 5. GIT sections weighed to determine effect of different levels of maize bran on their size were the gizzard together with proventriculus, the small intestine, the caecae, the colon and the liver as an accessory organ for digestion.

< Mean weight for abdominal fat was determined as an indicator (Griffiths et al., 1978; Becker et al., 1979; Sonaiya, 1985) of body fat content for birds on the different treatment diets. Abdominal fat was that fat surrounding the gizzard, extending within the ischium and surrounding the bursa of Fabricius, cloaca, and adjacent abdominal muscles.

3.56 Chemical Analyses

Samples from the maize, soyabean meal and maize bran used in the feed formulations were analysed for dry matter (DM), crude protein (CP), calcium and phosphorus content to determine the level of incorporation of each ingredient. Dicalcium phosphate samples were analysed for calcium (Ca) and phosphorus (P) content and limestone meal samples were only analysed for calcium content.

Samples from pre-starter and starter feed formulations were analysed for CP, ash, Ca and P content as the correct levels of these three nutrients are very important for optimum muscle and bone tissue development in early growth.

Samples from all four finisher feed formulations and faecal samples (8) from digestibility trials of Arbor acres and Cobb birds, respectively, fed on each of the four finisher feed formulations, were analysed for DM, CP, EE, ash, Ca, P, neutral detergent fibre (NDF) and gross energy (GE).

All samples were prepared for analysis by grinding to pass through a sieve with 1 mm openings. The ground samples were then mixed thoroughly (AOAC, 1998). All samples were analysed in duplicate. Chemical analysis procedures are described in Appendix B.

3.6 STATISTICAL ANALYSIS

3.61 Analysis of Variance

Analysis of variance (ANOVA) was done for liveweight, feed consumption feed conversion ratio, carcass characteristics, feed costs and gross margin returns of all treatments to find out significant differences (if any) among the treatment means. ANOVA was done for liveweight, feed consumption and feed conversion ratio, feed costs and gross margin returns at 43 and 47days of age of the birds. At about six weeks of age, marketing of Arbor acres birds usually begins and, therefore it was decided that analysis of the performance parameters at this age was necessary .The parameters were analysed in a Randomised Complete Block Design, 3 factor (factorial) model using Michigan State University Statistical Program Version C. Duncan's Multiple Range Test (DMRT) was used to separate means according to *Little and Hills (1978)* and *Gomez and Gomez (1984).*

3.62 Linear Correlations

Bivariate linear correlations were done for liveweight, feed consumption feed conversion ratio and carcass characteristics of all treatments according to *Little and Hills (1978)* . The Statistical Program for Social Sciences (SPSS, 1997) was used to produce correlation matrices for the mentioned parameters, organised according to strains and feeding dates.

3.63 Regression Analysis

Regression analysis was done according to *Little and Hills (1978)*. The Statistical Program for Social Sciences (SPSS,1997) was used to estimate linear and quadratic functions for the relationship between maize bran levels in the treatment diets and digestibility of nutrients in the experimental birds. Microsoft Excel Program (1995) was used to draw line graphs showing the relationship between apparent digestibility coefficients of the analysed nutrients and maize bran level in the diet.

3.7 PREPARATION OF HISTOLOGICAL SECTIONS (According to UNZA Vet. Med. Pathology Lab Manual, 1990)

3.71 Preservation of Tissues

Two birds were randomly selected from each of the 14 treatments at 53 days of age. The ileum, colon, and caeca of the birds were removed for histological examination. These 3 areas of the gastrointestinal tract were selected because of the possibility of microbial activity in them. Of the 2 most important coccidial species, Eimeria tenella invades the caeca and E. necatrix the small intestine, though part of the life cycle of E. necatrix may be spent in the caeca *(Hall, 1977)*.

The 28 birds were slaughtered and gastrointestinal tract removed. Sections of approximately 5 cm were removed about 10 cm above the ileocaecal junction. 5 cm caecae sections were cut from 2 cm away from the blind end inwards. The colon was just about 5 cm and so all of it was removed. The 5 cm sections had their lumen contents washed out with water and then sections from the same bird were placed in a labelled 250 ml container having about 100 ml of 4% formalin for preservation. The formalin hardens tissues by coagulation and denaturation of protein. It also arrests autolysis and bacterial decomposition (*Thomas and Richter, 1984)*. Good preservation is achieved after soaking in 4% formalin for 4 days.

3.72 Preparation of Tissues for Microtome Sectioning

Tissues of about 5 mm thickness were cut from the preserved tissue using sharp blades. The 5mm tissues were placed in tissue baskets and washed under running tap water for an hour to remove the formalin. The tissues were dehydrated by passing them through a series of increasing strengths of ethanol (70%, 80%, 90%, 100%) and then through xylene using an

Automatic Tissue Processor. The gradual change in ethanol concentration was done to avoid damage to tissues through undue shrinkage and hardening. The xylene removed and replaced the ethanol as well as making the tissues transparent or "clear".

The tissues were then embedded in paraffin to produce a firm homogeneous mass. The process involved placing the cleared tissues from xylene in an embedding tray containing liquid paraffin at 60 ^{0}C (melting point is 56 ^{0}C). When the tissue was empregnated with paraffin (20 minutes), the embedding tray, with contents was placed in a cold water bath to cool and then a freezer to completely solidify. The embedded tissue acquired a good firm consistency for cutting with a microtome.

The mass of tissues embedded in one block were separated into individual blocks which were trimmed around the edge to leave about 2mm of wax around the tissue. The blocks were then attached to labelled wooden block holders.

3.73 Mounting of Sections on Slides and Staining

Four micrometer thick sections of the tissues cut on a microtome were floated in a warm water bath to stretch them out and then picked out using clean slides. After drying the slides on a warm plate for 24 hours the staining process started with removal of the paraffin wax used for embedding the tissues. Xylene was used to remove the wax. The tissues on the slides were then re-hydrated by passing them through a series of decreasing strength ethanol (100%, 90%, 80%, 70%) and then rinsed in tap water.

The stains used were haematoxylin [a blue staining basic dye which binds electrostatically to phosphate groups of nucleic acids, and carboxyl groups of proteins and mucopolysaccharides. It is picked by nuclei, basophilic cytoplasm, bacteria and calcium (*Thomas and Richter, 1984)*] and eosin [an acidic red staining dye which binds predominantly with the positively charged amino group of proteins. It is picked up by cytoplasm, connective tissue and all other tissues (*Thomas and Richter, 1984)*]. In paraffin embedded tissue sections the fat is dissolved by alcohol leaving optically empty spaces *(Thomas and Richter, 1984)*. After staining, excess and soluble dye in the tissue was removed in running tap water. The tissues were then dehydrated in a series of increasing strength ethanol (70%, 80%, 90%, 100%) and finally cleared in xylene before mounting in permount, a mounting medium, and placing cover slips over them.

A light microscope was used to examine the slides for morphological differences and coccidial invasion.

CHAPTER IV

4.0 RESULTS AND DISCUSSION

Analysis of variance (ANOVA) tables for all parameters studied are in Appendix D. Analysis of variance for all the parameters measured showed a highly significant difference ($P \leq 0.01$) between the Arbor acres and Cobb strains. This indicated that the two strains are genetically different. Arbor acres recorded higher weights for all parameters of weight and dressing out percentage and had better feed conversion ratios and higher feed intake than Cobb birds.

While ANOVA was used to analyse treatment means for significant differences, linear correlation coefficients in Table 4.3 were used to determine whether bran level in the diet had a negative or positive relationship with the analysed parameters. *Snedecor and Cochran (1989)* explained that in a bivariate normal distribution when the coefficient of linear correlation (r) is 0.5 or less, only a minor portion of the variation in one variable can be attributed to its linear regression on the other variable. At r = 0.7, about half the variance of one variable is associated with variation in the other variable. At r = 0.9, about 80% of the variance of one variable is associated with the variation in the other variable. Linear correlation coefficients are discussed only for parameters where significant coefficients occur. Complete linear correlation coefficient matrices for bran level, liveweight, feed consumption, feed conversion ratio and carcass characteristics are in Appendices E i) and E ii) for Arbor acres birds fed bran containing diets from day 29 and day 35, respectively; and in Appendices E iii) and E iv) for Cobb birds fed bran containing diets from day 29 and day 35, respectively. Significant linear correlation coefficients are appropriately indicated. Below is a discussion of results for each parameter measured and analysed.

4.1 LIVE WEIGHT

Cobb chicks were smaller (mean live weight: 30.3 g) at day old than Arbor acres chicks (mean live weight 47.5 g). The Cobb birds had consistently lower mean weights than the Arbor acres birds on all weighing days (Appendix C). Mean live weights for Arbor acres were 1.78 kg and 1.90 kg at 43 days and 47 days, respectively. Those for Cobb were 1.32 kg and 1.43 kg at 43

Table 4.1: MEANS OF LIVEWEIGHT (L.WT), FEED CONSUMPTION (F. CONS) AND FEED CONVERSION RATIO (FCR) AT 43 DAYS AND 47 DAYS OF AGE; AND LIVEWEIGHT (L.WT) AT 48 DAYS OF AGE.

TREATMENT[&]	AT 43 DAYS			AT 47 DAYS			AT 48 DAYS
	L.WT kg	F. CONS. kg	FCR	L.WT kg	F. CONS. kg	FCR	L.WT kg
A/0/29	1.784a	3.170a	1.78a	1.898a	3.697a	1.95a	2.187a
A/10/29	1.769a	3.260a	1.84a	1.932a	3.771a	1.95a	2.067a
A/20/29	1.738a	3.160a	1.82a	1.883a	3.660a	1.94a	2.067a
A/30/29	1.794a	3.118a	1.74a	1.898a	3.607a	1.90a	2.027a
A/0/35	1.784a	3.170a	1.78a	1.898a	3.697a	1.95a	2.187a
A/10/35	1.755a	3.216a	1.83a	1.913a	3.752a	1.96a	2.053a
A/20/35	1.832a	3.273a	1.79a	1.937a	3.847a	1.99a	2.120a
A/30/35	1.751a	3.050a	1.74a	1.803a	3.476a	1.97a	1.987a
C/0/29	1.310b	2.601b	2.00b	1.418b	3.076b	2.17b	1.587b
C/10/29	1.350b	2.585b	1.91b	1.436b	3.028b	2.12b	1.627b
C/20/29	1.347b	2.715b	2.02b	1.433b	3.201b	2.23b	1.587b
C/30/29	1.333b	2.528b	1.90b	1.418b	3.015b	2.13b	1.440b
C/0/35	1.310b	2.601b	2.00b	1.418b	3.076b	2.17b	1.587b
C/10/35	1.276b	2.629b	2.06b	1.397b	3.040b	2.18b	1.507b
C/20/35	1.332b	2.573b	1.93b	1.475b	3.035b	2.06b	1.587b
C/30/35	1.301b	2.463b	1.89b	1.413b	2.930b	2.07b	1.520b
MEAN	1.549	2.880	1.88	1.661	3.348	2.05	1.821
CV (%)	4.29	5.18	7.15	4.92	7.00	7.65	7.36

Means in the same column followed by the same letter are not significantly different from each other ($P \leq 0.01$).

[&] A = Arbor acres strain; C = Cobb 500 strain; 0, 10, 20, 30 = % Maize bran in finisher feed; 29, 35 = Days of age of birds.

days and 47 days, respectively. Table 4.1 shows that mean live weights for the different treatments within the same strain were not significantly different at both 43 and 47 days of age. There were no significant interactions between strain, the date of starting to feed diets containing bran and bran level.

4.2 FEED CONSUMPTION

Mean feed consumption (Table 4.1) was higher for Arbor acres and was 3.18 kg and 3.69 kg at 43 and 47 days respectively. Cobb birds recorded a mean feed consumption of 2.58 kg at 43 days and 3.05 kg at 47 days. There was no significant difference in mean feed consumption for treatments within the same strain at 43 and at 47 days. There were no significant interactions between strain, date of starting to feed diets containing maize bran and bran level.

4.3 FEED CONVERSION RATIO

Arbor acres birds were better converters of all the experimental diets into meat (Table 4.1). Mean feed conversion ratio (FCR) for Arbor acres birds was 1.79 at 43 days and 1.95 at 47 days. For the Cobb birds mean FCR was 1.96 at 43 days and 2.14 at 47 days. There was no significant difference in mean FCR for treatments within the same strain and no significant interactions between strain, date of starting to feed diets containing maize bran and maize bran level.

4.4 CARCASS CHARACTERISTICS

4.41 Dressed Weight

There was highly significant difference *($P \leq 0.01$)* in mean dressed weights (Table 4.2) for Arbor acres (1.42 kg) and Cobb birds (0.99 kg). The larger Arbor acres birds produced larger dressed carcasses. Significant difference *($P \leq 0.05$)* was observed between mean dressed weight for birds of both strains fed the diet containing 30% maize bran (mean dressed weight:1.15 kg) and those on 0% and 20% maize bran level (mean dressed weight: 1.26 kg and 1.23 kg respectively). The birds on 30% bran level had lower mean dressed weights. These birds also had lower (not significantly) mean dressed weights than birds on the diet containing 10% maize bran (mean dressed weight: 1.21 kg). The lower mean dressed weight of the birds on the diet containing 30% maize bran can be attributed to the significantly lower *($P < 0.10$)* mean

liveweights of the birds at slaughter, on day 48 (Appendix D vii). The lower liveweight of the birds on 30% maize bran level could indicate some nutritional inadequacy in the diet which may be attributed to the nutrient diluting effect of the bulky maize bran.

Strong negative linear correlation coefficients (Table 4.3) for bran level with dressed weight indicated a decrease in mean dressed weight with increase in maize bran levels in the diet, for Arbor acres birds. Correlation coefficients were -0.99 (significant at $P \leq 0.01$) and -0.92 for Arbor acres birds fed diets containing maize bran from day 29 and day 35, respectively.

4.42 Dressing Out Percentage

Table 4.2 shows that the Arbor acres carcasses had significantly higher ($P \leq 0.01$) mean dressing out percentages (68.1%) than the Cobb carcasses (63.7%). There was significant interaction ($P \leq 0.01$) between strain and bran level. Mean dressing out percentage generally decreased with increase in maize bran levels in Arbor acres. The 10% maize bran level mean dressing out percentage (68.9%) and 0% maize bran level mean dressing out percentage (68.7%) were higher than those recorded at 30% maize bran level (67.5%) and 20% maize bran level (67.3%). In Cobb birds a general increase in mean dressing out percentage was observed. Cobb birds on the diet containing 0% maize bran had the lowest mean dressing out percentage (63.0%) followed by those on 10% bran level (mean dressing out percentage: 63.4%), then birds on 30% bran level (mean dressing out percentage: 63.6%) and finally those on 20% bran level (mean dressing out percentage: 65.0). This showed that differences can be expected in the general response of the two strains, in their dressing out percentages, to varying levels of maize bran in the finisher diet.

4.43 Weight of Small Intestine

Table 4.2 shows that Arbor acres birds had significantly ($P \leq 0.01$) heavier small intestine mean weight (70.98 g) than Cobb birds (57.46 g). Birds from both strains which were fed the finisher diet containing 30% maize bran had significantly ($P \leq 0.01$) lower small intestine mean weight (59.93 g) than birds on 0%, 10% and 20% maize bran levels. Mean small intestine weights for birds on the other diets were 66.70 g, 64.33 g and 65.92 g for the 0%, 10% and 20% bran levels respectively. The significantly lower small intestine mean weight for birds on the

Table 4.2: MEANS OF CARCASS CHARACTERISTICS AT 48 DAYS

TREATMENT[&]	CARCASS* kg	D.OUT %	SI g	LIVER g	G+P g	A.FAT g	COL g	CAECAE g
A/0/29	1.502a	68.7ab	75.3a	51.1a	66.3abc	39.5abc	5.5ab	12.0abcd
A/10/29	1.430a	69.2a	72.7ab	37.4bcde	65.4abc	42.4abc	5.3ab	12.0abcd
A/20/29	1.399a	67.7ab	69.0abc	41.5bc	69.2a	46.1ab	5.0ab	12.5ab
A/30/29	1.351a	66.7bc	66.5bcd	42.5b	67.9ab	48.1a	5.7a	11.7bcde
A/0/35	1.502a	68.7ab	75.2a	51.1a	66.3abc	39.5abc	5.5ab	12.0abcd
A/10/35	1.411a	68.7ab	69.8abc	41.0bcd	66.0abc	37.8abc	5.1ab	12.3abc
A/20/35	1.420a	67.0abc	75.3a	49.7a	64.7abc	35.7abc	5.7a	13.1a
A/30/35	1.358a	68.4ab	64.3cde	39.1bcde	66.3abc	27.2c	4.9ab	13.2a
C/0/29	1.000b	63.0e	58.3efg	34.9cdef	59.5abc	27.8c	5.5ab	11.1de
C/10/29	1.035b	63.6de	61.8def	36.7bcde	58.1bc	38.6abc	5.1ab	12.0abcd
C/20/29	1.022b	64.4de	59.6defg	34.3def	65.5abc	31.2bc	4.8ab	12.6ab
C/30/29	0.911b	63.3e	54.5fg	32.5ef	58.6bc	40.9abc	4.9ab	10.7e
C/0/35	1.000b	63.0e	58.3efg	34.9cdef	59.5abc	27.8c	5.5ab	11.1de
C/10/35	0.953b	63.2e	53.0g	36.7cde	56.8c	30.3bc	4.7ab	11.5bcde
C/20/35	1.038b	65.5cd	59.8defg	28.3f	57.9bc	27.6c	4.9ab	11.0de
C/30/35	0.970b	63.9de	54.4fg	35.9bcde	58.7bc	30.5bc	4.4a	11.1cde
MEAN	1.21	65.9	64.2	39.2	62.9	35.7	5.2	11.9
CV (%)	7.24	1.75	6.08	9.32	8.20	23.21	11.48	5.42

Means in the same column followed by the same letter are not significantly different from each other ($P \leq 0.05$).

[&] A = Arbor acres strain; C = Cobb 500 strain; 0, 10, 20, 30 = % Maize bran in finisher feed; 29, 35 = Days of age of birds.

* Viscera, abdominal fat, neck, head, feet removed.

Table 4.3: LINEAR CORRELATION COEFFICIENTS FOR BRAN LEVEL WITH MEANS OF LIVEWEIGHT, FEED CONSUMPTION, FCR AND CARCASS CHARACTERISTICS

PARAMETER	ARBOR ACRES		COBB 500	
	DAY 29	DAY 35	DAY 29	DAY 35
Liveweight at 43 days	-0.01	-0.08	+0.47	+0.16
Feed Consumption at 43 days	-0.55	-0.41	-0.15	-0.84
Feed Conversion Ratio at 43 days	-0.41	+0.68	-0.40	-0.79
Liveweight at 47 days	-0.31	-0.57	-0.04	+0.24
Feed Consumption at 47 days	-0.71	-0.47	-0.02	-0.91
Feed Conversion Ratio at 47days	-0.87	+0.46	-0.03	-0.85
Liveweight at 48 days	-0.86	-0.79	-0.76	-0.39
Dressed weight	-0.99**	-0.92	-0.65	-0.02
Dressing Out %	-0.87	-0.41	+0.37	+0.57
Small Intestine weights	-0.99**	-0.67	-0.57	-0.20
Liver weights	-0.49	-0.58	-0.72	+0.08
Gizzard and Proventriculus weights	+0.66	-0.22	+0.18	-0.13
Abdominal Fat weights	+0.99**	-0.92	+0.67	+0.45
Caeca weights	+0.13	-0.43	-0.88	-0.86
Colon weights	-0.16	+0.96*	-0.99**	-0.29

* *Significant at $P \leq 0.05$*

** *Significant at $P \leq 0.01$*

30% maize bran level can be attributed to their significantly lower mean liveweight at slaughter, on day 48. There was significant interaction *($P \leq 0.05$)* between bran feeding dates and bran levels. Small intestine mean weights generally decreased with increase in bran level for birds fed maize bran containing diets from day 29. Birds fed the diet containing 30% maize bran from 29 days of age had significantly lower *($P \leq 0.05$)* small intestine mean weight (60.51 g) than

those on 0% and 10% bran levels (small intestine mean weights: 66.71 g and 67.27 g, respectively) but not those on 20% bran level (small intestine mean weight: 64.27). It can, therefore, be said that feeding a finisher diet containing 30% maize bran from 29 days did not result in an increase in small intestine mean weights, contrary to other findings where weight of intestines increased in response to high fibre (wheat bran, oat bran and pea fibre) intake in rats *(Hansen et al., 1992).*

Linear correlation coefficients (Table 4.3) for bran level with small intestine mean weights indicated a decrease in small intestine mean weights with increase in maize bran levels in the diet for all the birds. Arbor acres correlation coefficients were stronger at -0.99 (significant at $P \leq 0.05$) and -0.67 for birds fed diets containing bran from day 29 and day 35 respectively. Cobb correlation coefficients were weaker at -0.57 and -0.20 for birds fed diets containing bran from day 29 and day 35 respectively.

4.44 Weight of Liver (Table 4.2)

Arbor acres birds had significantly higher ($P \leq 0.01$) liver mean weight (44.19 g) than Cobb birds. Birds on finisher diet without maize bran had significantly higher ($P \leq 0.01$) liver mean weights (43.00 g) than birds on 10%, 20% and 30% maize bran levels (liver mean weight: 37.97g, 38.44 g and 37.51 g respectively). There was significant interaction between strain and maize bran level. Arbor acres birds fed the finisher diet without maize bran had significantly higher ($P \leq 0.01$) liver mean weight than birds of the same strain on 10% and 30% maize bran levels (mean liver weights: 39.21 g and 40.84 g, respectively); and higher liver mean weight, though not significantly, than those on 20% maize bran level (liver mean weight: 45.61 g). The results indicate that adding maize bran to the finisher diet of the broilers caused a reduction in liver size for Arbor acres birds. This could be due to low fat accumulation in the liver for birds on high fiber diet.

4.45 Weight of Gizzard and Proventriculus (Table 4.2)

The larger Arbor acres birds had significantly higher ($P \leq 0.01$) gizzard and proventriculus mean weights (66.53 g) than Cobb birds (59.35 g).

4.46 Weight of Abdominal Fat (Table 4.2)

There was significant difference *($P \leq 0.01$)* in abdominal fat mean weights. The larger Arbor acres birds had a higher abdominal fat mean weight of 39.55 g than the smaller Cobb birds which had an abdominal fat mean weight of 31.84 g. However, birds from both strains fed the maize bran containing diets from day 29 had significantly higher *($P \leq 0.01$)* abdominal fat mean weight (39.33 g) than those fed bran containing diets from day 35 (abdominal fat mean weight: 32.02 g). The diets containing maize bran had a higher fat content than the control diet (0% maize bran level), partly contributed by the bran, which had an ether extract of 8.8% (Appendix Aii). *Carew et al. (1964)* demonstrated that 10-15% more energy was deposited in the carcass of chickens receiving diets containing 5-10% fat compared to similar diets low in fat. They concluded that the efficiency of utilisation of energy consumed is improved when fats are included in diets for growing animals. The fat content of the experimental diets, expressed as ether extract were 3.80%, 4.60%, 5.20% and 5.37% for the 0%, 10%, 20% and 30% maize bran containing diets (Appendix A ii). This means that the fat in the diets containing 20% and 30% maize bran improved the efficiency of energy utilisation in the birds. *Forbes and Swift (1944)*, while working with rats, observed that the efficiency of utilisation of energy consumed was improved even when the metabolizable energy intake from the low fat and higher fat diets were the same. They termed it the associative dynamic action of fats. *Scott et al (1982)* listed corn oil among the fats having such a physiological effect.

Linear correlation coefficients (Table 4.3) for maize bran level with abdominal fat mean weights indicated that abdominal fat mean weights decreased only for Arbor acres birds fed maize bran containing diets from 35 days of age. All the other birds showed a positive relationship between maize bran level in the diet and abdominal fat mean weight. Correlation coefficients for the Arbor acres birds were strong at +0.99 (significant at $P \leq 0.01$) and -0.92 for birds fed diets containing bran from day 29 and day 35 respectively while those for Cobb birds were weaker at +0.67 and +0.45 for birds fed diets containing bran from day 29 and day 35 respectively. It appears that the Arbor acres birds may not have been able to beneficially utilize the so called "dynamic action of fats" when the higher fat containing finisher diets were introduced at day 35.

4.47 Weight of Caeca (Table 4.2)

There was significant difference *($P \leq 0.01$)* in caeca mean weights with the Arbor acres birds having a higher caeca mean weight of 12.37 g, while Cobb bird caeca mean weight was 11.38 g. There was significant difference *($P \leq 0.05$)* between the caeca mean weights for birds on the 20% maize bran level and those on the 0% and 30% maize bran levels. Caeca mean weight was 12.32 g for birds on the diet containing 20% maize bran while those for birds on 0% and 30% maize bran levels were 11.54 g and 11.69 g respectively. Caeca mean weight for birds on the 10% maize bran level was 11.97 g. There was significant interaction *($P \leq 0.01$)* between strain and date of starting to feed bran in the finisher diets. Arbor acres birds fed diets containing bran from day 35 had higher (though not significantly) caeca mean weight (12.07 g) than those fed diets containing bran from day 29 (caeca mean weight: 12.67 g). Cobb birds fed diets containing bran from day 29 had higher caeca mean weight (11.59 g) than those fed from day 35 (caeca mean weight: 11.19g).

4.48 Weight of Colon (Table 4.2)

Arbor acres birds had significantly higher *($P \leq 0.05$)* colon mean weights (5.31 g) than Cobb birds (4.90 g).

Linear correlation coefficients (Table 4.3) for bran level with colon mean weights indicated that colon mean weights increased with increase in bran levels only for Arbor acres birds fed diets containing bran from day 35. The linear correlation coefficient for these birds was positively strong at +0.96 (significant at $P \leq 0.05$). Cobb birds fed diets containing bran from day 29 had a strong negative linear correlation coefficient at -0.99 (significant at $P \leq 0.01$), indicating a decrease in colon mean weights with increase in bran levels in the diet. The correlation coefficient for the Arbor acres birds fed diets containing bran from day 29 was -0.16 while that for Cobb birds fed diets containing bran from day 29 was -0.29.

4.5 APPARENT DIGESTIBILITY OF TREATMENT DIETS (Table 4.4)

Linear and quadratic functions (Appendix G) were estimated to analyse apparent digestibility of nutrients with increase in maize bran in finisher feed, from 0% to 30%. Regression lines for the apparent digestibility coefficients of the different nutrients were not extrapolated beyond the 0% to 30% maize bran level range. Where both the linear and quadratic functions were not significant *($P \leq 0.05$)*, cubic functions were not estimated as the accuracy of these functions would not be justified by the results which were based on only one experiment and on only one pair of observations more than the recommended minimum of three observations for a line graph *(Gomez and Gomez, 1984).*

Table 4.4: APPARENT DIGESTIBILITY COEFFICIENTS AND APPARENT METABOLIZABLE ENERGY AT EIGHT WEEKS.

TREATMENT[&]	DM[b] %	CP[c] %	EE[d] %	NDF[e] %	Ca[f] %	P[g] %	AME[h] K cal/kg
A/0	74.8	56.9	78.9	47.9	24.9	5.8	2.955
A/10	67.6	53.7	82.2	29.6	27.5	1.8	2.789
A/20	63.3	49.3	80.2	20.3	22.1	1.2	2.742
A/30	62.4	52.2	77.7	25.3	24.6	3.3	2.794
C/0	73.7	56.9	75.1	43.2	19.9	3.2	2.917
C/10	66.9	49.0	74.3	33.9	19.0	2.7	2.817
C/20	63.5	48.1	76.3	29.5	12.4	2.5	2.749
C/30	61.7	47.1	78.3	27.4	26.5	3.7	2.727

[&] A = Arbor acres strain; C = Cobb 500 strain; 0, 10, 20, 30 = % Maize bran in finisher feed;

[b] Dry matter

[c] Crude protein

[d] Ether Extract

[e] Neutral Detergent fibre

[f] Calcium

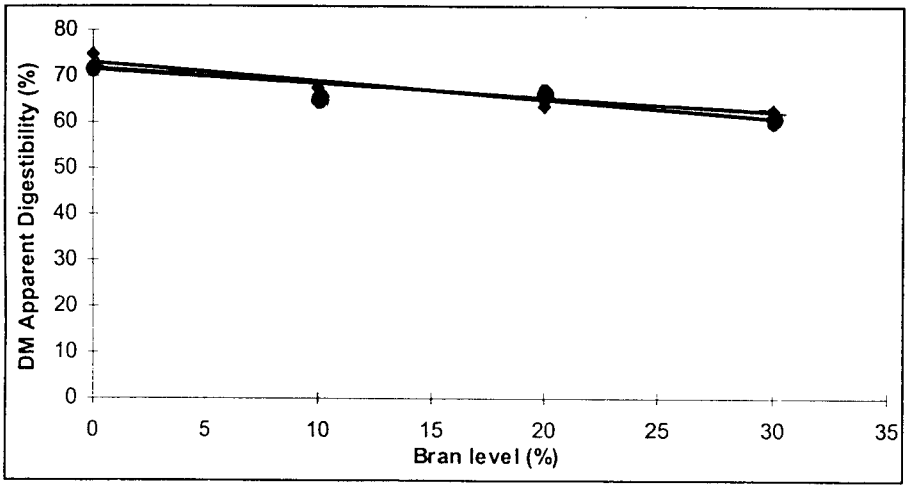
[g] Phosphorus

[h] Apparent Metabolizable Energy

4.51 Dry Matter (Figure 2.)

In both Arbor acres and Cobb birds apparent digestibility of dry matter (DM) decreased by approximately 12% with increase in maize bran in the finisher feed. Dry matter apparent digestibility decreased from 74.8% to 62.4% in Arbor acres birds and decreased from 73.7% to 61.7% in Cobb birds. Dry matter apparent digestibility decrease was significantly linear *($P \leq 0.05$)* for both Arbor acres and Cobb For both Arbor acres and Cobb birds, DM apparent digestibility decreased linearly with increase in maize bran level in the diet *($P \leq 0.05$).*

Figure 2. Dry Matter Apparent Digestibility Trends



Arbor acres

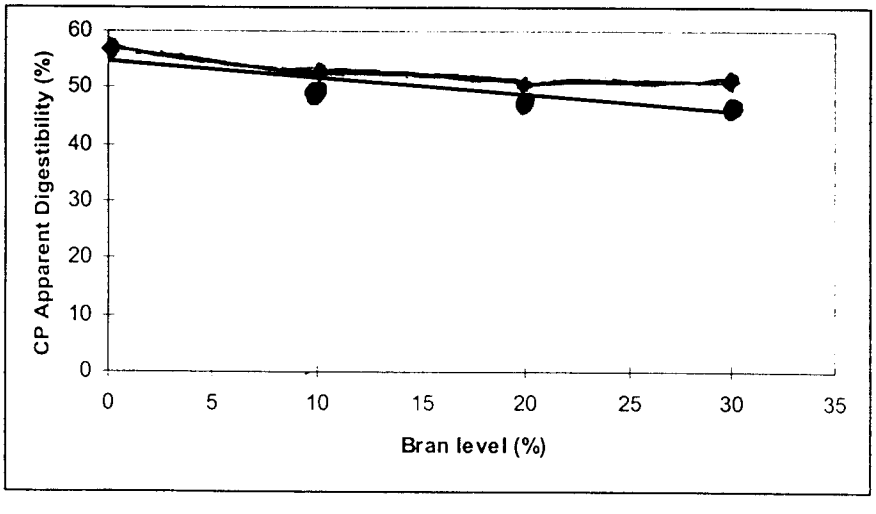
Cobb 500

4.52 Crude Protein (Figure 3.)

Apparent CP digestibility was the same (56.9%) in both strains on the 0% maize bran level. Thereafter, the two strains' apparent protein digestibility took different trends. In Arbor acres both the linear and quadratic functions were not significant *($P \leq 0.10$).* The multiple coefficient of correlation for the quadratic function was 0.94 and indicated a better fit to the CP apparent digestibility data which decreased from 0% to 20% maize bran level (CP apparent digestibility:49.3%) and then increased up to the 30% bran level (CP apparent digestibility: 52.2%). It can therefore be said that CP apparent digestibility for Arbor acres was curvilinear.

Apparent digestibility of CP in Cobb decreased from 0% bran level to 30% bran level (CP apparent digestibility: 47.1%) in the finisher diet. The linear trend accounted for 87.2% of the variability due to CP apparent digestibility and maize bran level in the diet. A coefficient of linear correlation of -0.87 indicated a close negative linear relationship between the CP apparent digestibility coefficients and maize bran level in the diet. Crude protein apparent digestibility in Cobb birds decreased linearly from the 0% to 30% maize bran level in the diet.

Figure 3. Crude Protein Apparent Digestibility Trends

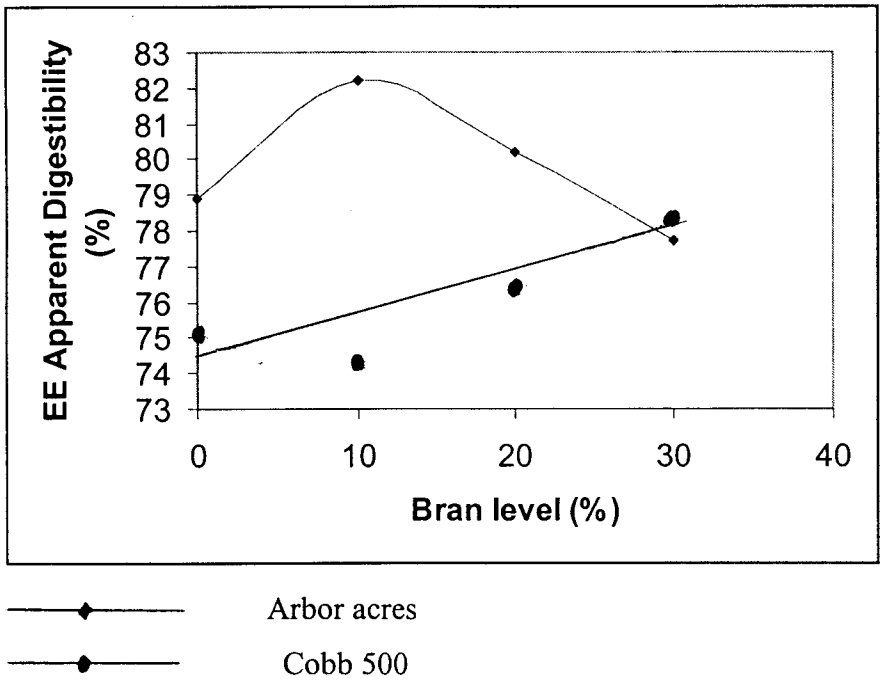


4.53 Ether Extract (Figure 4.)

Arbor acres apparent digestibility coefficients of EE increased from 0% bran level (EE apparent digestibility: 78.9%) to a maximum digestibility at 10% bran level (EE apparent digestibility: 80.2) and then decreased towards the 30% bran level (EE apparent digestibility:77.7%). A quadratic function having significance level at $P \leq 0.322$ and multiple coefficient of correlation of 0.95 fitted the Arbor acres EE apparent digestibility better than the linear function having significance level at $P \leq 0.625$ and coefficient of linear correlation of -0.38. Observation can therefore, be made that EE apparent digestibility for Arbor acres was curvilinear

Ether extract apparent digestibility for Cobb decreased from 0% maize bran level (EE apparent digestibility: 75.1%) to 10% maize bran level (EE apparent digestibility: 74.3%) and then increased up to the 30% maize bran level (EE apparent digestibility: 78.3%). A coefficient of linear correlation of 0.86 indicated a close positive linear relationship between EE apparent digestibility coefficients and maize bran level in the diet. The linear function accounted for 86.1% of the variability due to the relationship between EE apparent digestibility and maize bran level in the diet, and fitted the EE digestibility trend better. Ether extract apparent digestibility for Cobb increased linearly from 0% to 30% maize bran level in the diet.

Figure 4. Ether Extract Apparent Digestibility Trends

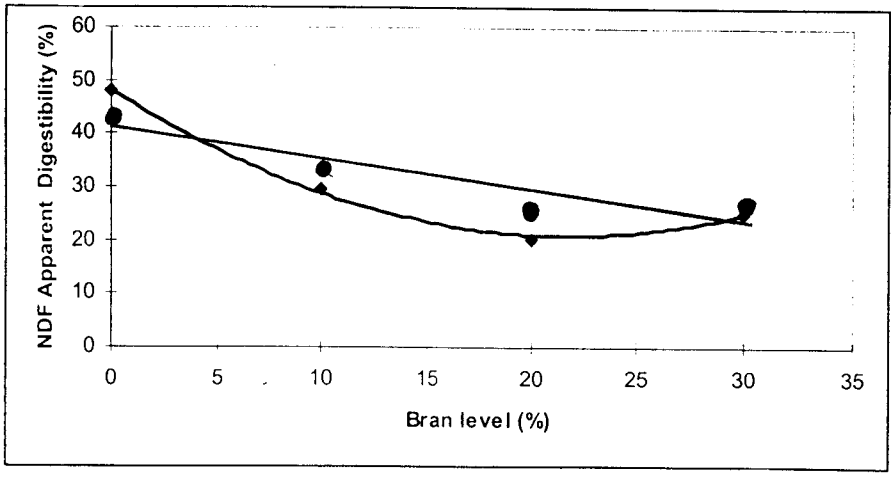


4.54 Neutral Detergent Fibre (Figure 5.)

Apparent digestibility of NDF in Arbor acres decreased from 0% bran level (NDF apparent digestibility: 47.9%) to 20% bran level (NDF apparent digestibility: 20.3%) and then increased up to the 30% bran level (NDF apparent digestibility: 25.3). The NDF apparent digestibility was significantly quadratic *($P \leq 0.057$).* A multiple coefficient of correlation of 0.998 indicated a very close relationship between NDF apparent digestibility coefficients and bran level in the Arbor acres birds. Therefore, NDF apparent digestibility for Arbor acres was curvilinear.

Cobb birds' apparent digestibility of NDF decreased from 0% bran level (NDF apparent digestibility: 43.2) to 30% bran level (NDF apparent digestibility: 27.4) in the finisher diet. The NDF apparent digestibility trend was significantly linear *($P \leq 0.046$).* A linear correlation coefficient of -0.99 indicated a very close relationship between NDF apparent digestibility coefficients and bran level. Neutral detergent fibre apparent digestibility for Cobb decreased linearly from 0% to 30% maize bran level in the diet.

Figure 5. Neutral Detergent Fibre Apparent Digestibility Trends



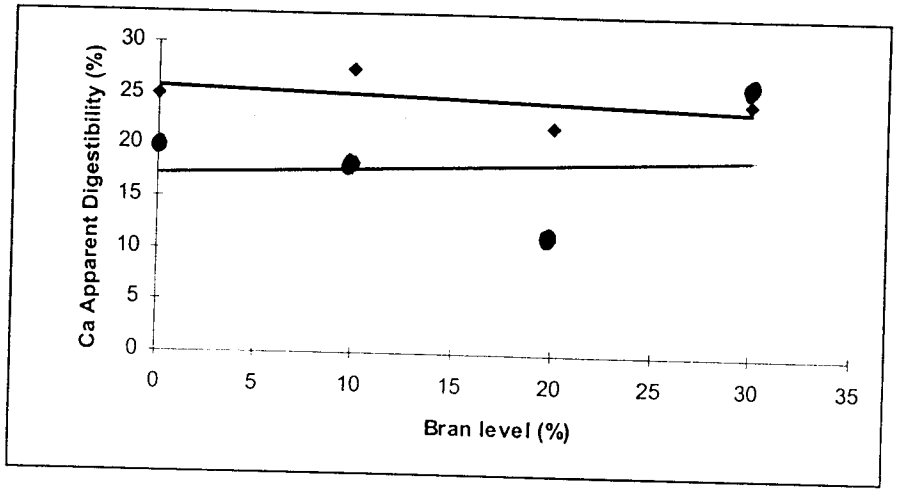
Arbor acres

Cobb 500

4.55 Calcium (Figure 6)

Calcium apparent digestibility showed no significant differences with increase in bran level and standard error values for the means were high.

Figure 6. Calcium Apparent Digestibility Trends



Arbor acres

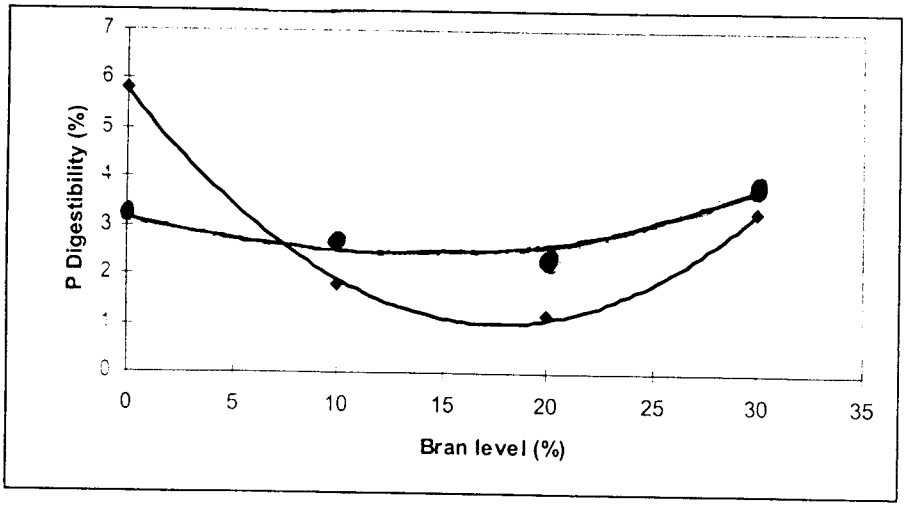
Cobb 500

4.56 Phosphorus (Figure 7.)

Phosphorus apparent digestibility in Arbor acres decreased from 0% bran level (P apparent digestibility: 5.8%) to 20% maize bran level (P apparent digestibility: 1.2%). Phosphorus apparent digestibility then increased up to the 30% maize bran level (P apparent digestibility: 3.3%). The quadratic function was significant *($P \leq 0.05$)* and also had a very good multiple correlation coefficient of 0.998.

Phosphorus apparent digestibility in Cobb decreased from 0% bran level (P apparent digestibility: 3.2%) to 20% maize bran level (P apparent digestibility: 2.5%) and then increased up to the 30% bran level (P apparent digestibility: 3.7%). Both the linear and quadratic *functions were not significant ($P \leq 0.05$) but the quadratic function had a good multiple* correlation coefficient of 0.965 . The significance level for the linear function was $P \leq 0.713$.

Figure 7. Phosphorus Apparent Digestibility Trends



Arbor acres

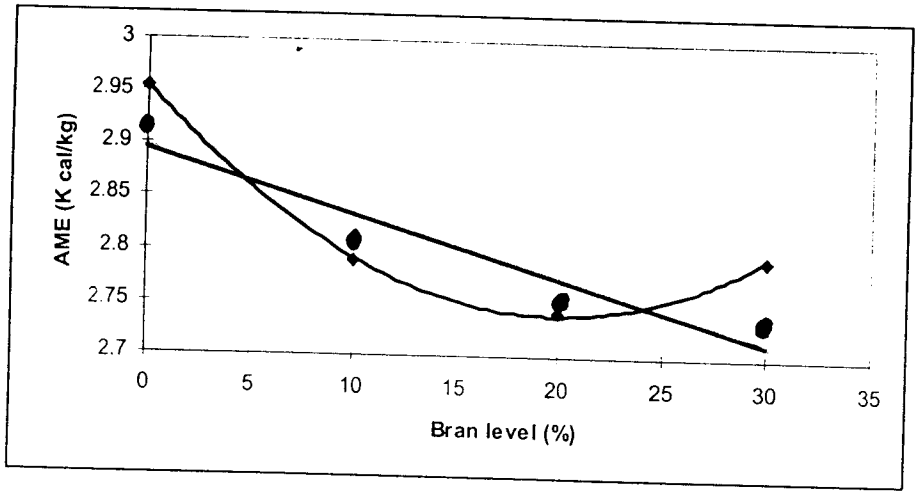
Cobb 500

4.57 **Apparent Metabolizable Energy** (Figure 8.)

In Arbor acres birds, there was a decrease in AME from 0% maize bran level (AME: 2.955 K cal /kg) to 20% maize bran level (AME: 2.742 K cal /kg) and then an increase in AME up to the 30% maize bran level (AME: 2.794 K cal /kg). The quadratic function was significant *($P \leq 0.028$)* and had a very good multiple correlation coefficient of 0.999. Apparent metabolizable energy for the Arbor acres birds was curvilinear. Indicating that the birds were showing some adaptation to increased fiber in the diet.

Cobb birds had a decrease in AME from 0% maize bran level (AME: 2.917 K cal /kg) to the 30% maize bran level (AME: 2.727 K cal /kg). The AME response was significantly linear *($P \leq 0.036$)* and had a good coefficient of linear correlation of -0.930. . Cobb AME decreased in a linear manner from the 0% maize bran level to the 30% maize bran level

Figure 8. Apparent Metabolizable Energy Trends



Arbor acres

Cobb 500

4.58 Comparison of Nutrient Apparent Digestibility in Arbor acres and Cobb

True digestibility of all the nutrients analysed could actually have been higher. Digestibility coefficients for Arbor acres were higher than those for Cobb for all nutrients, except for NDF digestibility coefficients for the diets containing 20% and 30% maize bran, which were higher in Cobb. Arbor acres birds appear to have a generally higher ability for digestion and absorption of all nutrients as evidenced by the higher apparent digestibility coefficients. This partly explains the better FCR's of the strain compared to those for Cobb. Apparent digestibility of DM decreased linearly with increase in maize bran in the diet for both Arbor acres and Cobb. In both strains the additional energy provided by the EE could have improved nutrient utilisation for the diets containing maize bran.

For Arbor acres birds quadratic trends fitting the apparent digestibility coefficients of CP, NDF, P and AME were characterised by a decrease in apparent digestibility from the 0% to the 20% maize bran level and then an increase up to the 30% maize bran level. This shows that there was some adaptation of the birds' digestive system to enable improved efficiency of digestion of the bulky feed containing 30% maize bran. The birds subjected to the digestibility trials were randomly selected from mixed birds which had fed on diets having the same maize bran level from both day 29 and day 35. It was therefore, not possible to determine the nature of the adaptation. However, Arbor acres birds fed bran containing diets from 29 days of age showed better adaptability to increasing maize bran levels in the diet than those fed from 35 days. The adaptation was exhibited an increase in abdominal fat mean weights with increase in maize bran levels in the diet. Mean live weights of the birds were not significantly different. Ether Extract digestibility was characterised by an increase in apparent digestibility from the 0% to 10% maize bran level and then a decrease up to the 30% maize bran level. This indicated that optimum EE digestion rate was achieved about the 10% maize bran level where EE content of the feed was 4.60%. Though apparent digestibility coefficients decreased beyond the 10% bran level, the actual amounts apparently digested increased. The amounts of EE consumed in the digestibility trial diets weighing 500 g were 17.18 g, 20.70 g, 23.42 g, 24.26 g, respectively for the 0%, 10%, 20% and 30% bran levels and corresponding amounts of EE apparently digested were 13.55 g, 17.01 g, 18.78 g and 18.86 g.

In Cobb birds, linear trends fitted the apparent digestibility coefficients for CP, NDF, AME as well as DM, already mentioned above. There was a general decrease in apparent digestibility of these nutrients though, this did not have any significant effect on performance of the birds in terms of significant differences in mean liveweights and FCR for the different treatments. Ether extract apparent digestibility increased linearly from the 0% bran level to the 30% maize bran level. This increase in EE digestibility is in conformity with the increase in abdominal fat mean weights with increase in maize bran levels. Phosphorus apparent digestibility was curvilinear. It decreased from 0% to 20% bran level before increasing up to the 30% maize bran level.

4.6 GASTROINTESTINAL TRACT MORPHOLOGICAL AND MICROFLORAL CHANGES

Sections of the ileum and colon for Arbor acres and Cobb birds fed the diets containing 20% and 30% maize bran showed proliferation of goblet cells and minor sloughing of the intestinal epithelium. No evidence of coccidial invasion of the cells or any other gut microfloral changes due to the diets containing maize bran was observed. The sloughing of the GIT epithelium did not appear to significantly affect the growth of the birds on higher bran level diets. The excess mucous produced by the birds' GIT to protect itself from the abrasive action of the bran also did not appear to have any significant effect on the performance of the birds. Sloughing of intestinal epithelial cells and increased mucous production agree with findings of other scientists. *Portman et al.(1985) Low (1989) and Ikegami et al. (1990)* reported that sloughed epithelial cells are expelled in larger amounts when experimental non-ruminant animals are fed purified diets supplemented with fibre. Excretion of higher levels of mucous (which is a glycoprotein) as well as sloughing of the epithelial lining of the ileum and colon for birds on 20% and 30% bran containing diets must have lowered the CP apparent digestibility coefficients.

4.7 MORTALITY RATE

At 47 days Arbor acres had a total mortality rate of 6.2% while that of Cobb was 1.8%.
The total mortality of 29 Arbor acres birds was more or less equally divided between the period covering the first and second week (14 chicks) and that of the fifth to seventh week (15 birds). In the first week the death of seven chicks was attributed to cold stress due to lack of artificial heat source on the first night. In the second week the death of another seven chicks was attributed to heat, water and nutritional stress. The cause of death of two of the 15 birds which

died in the fifth to seventh weeks was diagnosed as ascites by the University of Zambia School of Veterinary Medicine, Department of Clinical Studies. Ascites, which is also referred to as pulmonary hypertension syndrome *(Chapman et al., 1995)* is an accumulation of oedematous transudate (a low protein, non-inflammatory, watery fluid) in the peritoneal cavity *(Kelly et al., 1982)*, primarily caused by increased oxygen demand in the rapidly developing broiler and resultant congestive heart failure, due to a forced increase in output of blood by the heart *(Julian, 1993; Wideman and Bottje, 1993)*. Birds affected with ascites suddenly fell on their backs and almost immediately died with feet up and wings spread out. Nine of the birds died minutes after weighing or later in the day, on weighing days. Six were found dead, lying on their backs, on other days. Mortality of Arbor acres birds due to ascites indicated that the birds maintained a high growth rate even on the higher maize bran diets. *Shlosberg et al. (1991)* , *Arce et al. (1992)* and *Acar et al. (1995)* used feed restriction to slow rapid growth to reduce ascitic mortality successfully; however, they found that the final body weights of feed restricted birds did not attain the same body weight as controls.

Five of the eight Cobb mortalities were from the second to fourth days and were attributed to cold stress due to lack of artificial heat during the first night. The cause of death for the three older birds which died in the fifth week could not be determined by the University of Zambia School of Veterinary Medicine, Department of Clinical Studies.

4.8 FEED COSTS AND GROSS MARGIN RETURNS (Table 4.5)

Analysis of variance tables for finisher feed cost per bird and total feed cost per bird are in Appendices D xvi to D xxi. Gross margin budgets per bird are in Appendix F.

Finisher feed mean cost per bird and total feed mean cost per bird were significantly higher *($P \leq 0.01$)* for Arbor acres birds at both 43 days and 47 days than those for Cobb birds. Finisher feed mean costs at 43 days were K 1,319 for Arbor acres and K 1,059 for Cobb while total feed mean costs were K 2,212 for Arbor acres and K 1,813 for Cobb. At 47 days finisher feed mean costs per bird were K 1,663 for Arbor acres and K 1,353 for Cobb while total feed mean costs per bird were K 2,577 for Arbor acres and K 2,110 for Cobb. As observed earlier, under discussion of feed consumption, Arbor acres birds consumed significantly higher *($P \leq 0.01$)* quantities of feed than Cobb birds at both ages. This affected feed costs.

Table 4.5: MEAN FEED COSTS AT 43 AND 47 DAYS AND MEAN GROSS MARGIN RETURNS AT 47 DAYS OF AGE

&TREATMENT	43 DAYS OF AGE		47 DAYS OF AGE		
	FINISHER (K)	TOTAL (K)	FINISHER (K)	TOTAL (K)	GROSS MARGIN %
A/0/29	1,459a	2,341a	1,867a	2,763a	39.66d
A/10/29	1,408ab	2,306a	1,753a	2,666a	42.27cd
A/20/29	1,245bcd	2,146ab	1,543bc	2,444b	48.48abc
A/30/29	1,091def	1,972bc	1,362cdef	2,271bc	53.75a
A/0/35	1,459a	2.341a	1,867a	2,763a	39.66d
A/10/35	1,396ab	2,299a	1,743a	2,659a	42.30cd
A/20/35	1,349abc	2,292a	1,715ab	2,690a	41.62cd
A/30/35	1,141de	2,000bc	1,452cd	2,363b	50.92a
C/0/29	1,171cde	1,959bc	1,548bc	2,300bc	40.68d
C/10/29	1,052def	1,685d	1,339def	2,043de	49.74ab
C/20/29	1,093def	1,834cd	1,382cde	2,123cde	46.66abcd
C/30/29	930fg	1,671d	1,178fg	1,932e	54.08a
C/0/35	1,170cde	1,959bc	1,548bc	2,300bc	40.68d
C/10/35	1,187cde	1,971bc	1,444cde	2,227bcd	43.46bcd
C/20/35	853g	1,637d	1,140g	1,936e	53.87a
C/30/35	1,015efg	1,791cd	1,250efg	2,026de	50.23ab
MEAN	1,189	2013	1,508	2,344	46.12
CV (%)	8.90	5.76	8.34	5.92	10.25

Means in the same column followed by the same letter are not significantly different from each other ($P \leq 0.10$).

& A = Arbor acres strain; C = Cobb 500 strain; 0, 10, 20, 30 = % Maize bran in finisher feed; 29, 35 = Days of age of birds.

Feed costs for both strains significantly decreased with increase in maize bran level in the diet. At 43 days of age, the finisher feed mean costs for the 20% and 30% maize bran level in the diet (K 1135 and K 1044 respectively) were significantly lower *($P \leq 0.01$)* than those for the 0% and 10% maize bran levels (K 1315 and K 1261 respectively). Total feed mean cost for the diet containing 30% maize bran (K 1858) were significantly lower *($P \leq 0.01$)* than the total feed mean costs at 0% and 10% maize bran levels in the diet (K 2150 and K 2065 respectively). The total feed mean cost at the 20% maize bran level (K 1977) was significantly lower *($P \leq 0.01$)* than the total feed mean cost at 0% maize bran level in the diet. At 47 days, the finisher feed mean cost (K 1311) and total feed mean cost (K 2,148) for the 30% maize bran level in the diet were significantly lower *($P \leq 0.01$)* than the feed mean costs at 0% and 10% maize bran levels in the diet. Finisher feed mean costs were K 1708 and K 1570 at 0% and 10% maize bran levels respectively. Total feed mean costs were K 2532 and K2399 at 0% and 10% maize bran levels respectively. The finisher feed mean cost (K 1445.00) and total feed mean cost (K 2298.33)) were significantly lower *($P \leq 0.01$)* than the finisher and total feed mean costs at 0% maize bran level in the diet

Mean gross margin returns were calculated for the birds at 47 days of age only. Cobb mean gross margin returns (47.4%) were significantly higher *($P \leq 0.10$)* than those for the Arbor Acres birds (44.8%). Consideration was made that the Arbor acres birds suffered an unusually high mortality rate (6.2%), due to ascites. Mean gross margin returns were, therefore, calculated at the expected 2% mortality rate under good management. The calculated mean gross margin returns for Arbor acres were 54.16%, approximately 10% higher than the actual returns obtained

in the experiment. Mean gross margin returns obtained in the experiment for both strains indicated that the returns at the 30% maize bran level in the diet were significantly higher *($P \leq 0.01$)* than those at 0% and 10%. Mean gross margin returns were 52.25%, 47.66%, 44.44% and 40.17% at the 30%, 20%, 10% and 0% maize bran levels in the diet, respectively. Experimental mean gross margin returns at the 20% maize bran level in the diet were significantly higher *($P \leq 0.01$)* than those at the 0% bran level

4.81 Profitability of use of Maize Bran in Finisher Diets

It was evident that mean finisher feed costs had an effect on mean gross margin returns, resulting in improvement of the mean gross margin returns. The inclusion of maize bran, at the 20% and 30% level in broiler basal finisher gave significantly $(P \leq 0.01)$ better gross margin returns for both Arbor acres and Cobb birds than if no maize bran is added. The improved gross margins were achieved without significant effects on strain liveweight and FCR up to 47 days of age of the birds.

CHAPTER V

5.0 CONCLUSION.

Addition of up to 30% maize bran in the finisher feed fed to Arbor acres and Cobb broilers from 29 or 35 days of age did not have any significant effect on the growth rate of the birds. This means that maize bran was tolerated in the diets of these birds at higher levels than rice bran which does not affect growth of broilers only up to a level of 20% in the diet. The growth depressing and feed intake reduction effects generally expected of cereal fibre were not evident up to 47 days of age of the birds. Birds fed finisher feed containing 30% maize bran from 29 days of age had more fat deposited in their carcasses.

Apparent digestibility of DM decreased with increase in maize bran in the finisher feed for both Arbor acres and Cobb 500 birds. In both strains total amounts of EE apparently digested increased with increase in maize bran level in the finisher feed. The additional EE in the feeds containing maize bran could have enabled more efficient utilisation of energy and subsequently, other nutrients. Apparent digestibility of CP, NDF, P and AME in Arbor acres decreased from the 0% to the 20% maize bran level and then increased in birds fed finisher feed containing 30% maize bran. This indicated some adaptation of the birds' digestive system to enable more efficient digestion of the bulky feed containing 30% maize bran. In Cobb birds apparent digestibility for CP, NDF and AME decreased with increase in maize bran level in the finisher feed. This also shows strain difference in adaptation.

There were some GIT morphological changes induced by feeding the 20% and 30% maize bran containing feeds. There was a proliferation of goblet cells, in both strains, to increase mucous secretion for GIT protection against the abrasive action of the maize bran.

Broiler finisher feed containing 20% and 30% maize bran gave better gross margin returns in both Arbor acres and Cobb birds than feed containing no maize bran. Addition of 20% and 30% maize bran to finisher feed improved profits without significantly affecting the performance of birds of both strains up to the 47^{th} day.

Although the performance of both Arbor acres and Cobb 500 birds was not significantly affected by addition of up to 30% maize bran to the finisher feed, this may not be the same for other strains of broilers. Digestibility of nutrients in the treatment diets was different for the two strains, indicating variation in efficiency of digestion which could be genetically based. It would therefore, be necessary to establish performance of other strains through feeding trials before maize bran feeding levels can be recommended in commercial broiler rations.

Other feeding trials need to be done with Arbor acres and Cobb birds to determine the critical levels for adding maize bran to the feed as well as age at which to start feeding maize bran containing diets for optimum gross margin returns. Other feeding trials need to be done to verify changes in the gastrointestinal tract of the birds on feed containing 20% maize bran and over. Other digestibility trials need to be done to determine the standard true digestibility trends of Dry matter, Crude protein, Ether extract, Neutral detergent fibre, Calcium, Phosphorus and Metabolizable energy for the two strains when fed maize bran containing diets.

REFERENCES

Acar, N., F.G. Sizemore, G.R. Leach, R.F. Wideman, R.L. Owen and G.F.Barbato. 1995. Growth of broiler chickens in response to feed restriction regimens to reduce ascites. *Poultry Science.* 74: 833-843.

Adams ,O.L. and E.C. Nabler. 1969. Effect of physical and chemical treatment of grains on growth of and feed utilisation by the chick. 2. Effect of water and acid treatments of grains and grain components on chick growth, nitrogen retention and energy utilisation. *Poultry Science* 48: 922-928

Annison, G. 1990. Polysaccharide composition of Australian wheats and the digestibility of their starches in broiler chicken diets. *Australian Journal of Experimental Agriculture.* 30: 183-186

Annison, G. and M. Choct. 1991. Anti-nutritive activities of cereal non-starch polysaccharides in broiler diets and strategies minimising their effects. *World's poultry Science* 47: 232-242

Antoniou, T. and , R.R. Marquardt. 1981. Influence of rye pentosans on the growth of chicks. *Poultry Science* 60: 1898-1904

Antoniou, T.C., R.R. Marquardt, and E. Cansfield. 1981. Isolation, partial characterisation and anti-nutritional activity of a factor (pentosans) in rye grain. *Journal of Agriculture and Food Chemistry.* 29: 1240-1247

Antoniou, T. and , R.R. Marquardt. 1982. The utilisation of rye by growing chicks as influenced by autoclave treatment, water extraction and water soaking. *Poultry Science* 61: 91-102

AOAC. 1998. Official Methods of Analysis (16th Ed.). Assosciation of Official Analytical Chemists, Washington DC.

Arce, J., M. Berger, and C.L Coello.. 1992. Control of ascites syndrome by feed restriction techniques. *Journal of Applied Poultry Research.* 1: 1-5.

Austic, R.E. 1983. The availability of amino acids as an attribute of feeds in: Feed Information and Animal Production. Proceedings of the 2nd Symposium of the INTERNATIONAL NETWORK OF FEED INFORMATION CENTRES. Eds. Robards G.E and R.G. Packman. 175-189

Austic, R.E. and M.C Nesheim. 1970. Role of kidney arginase in variations of the arginine requirements of chicks. Journal of Nutrition. 100: 855

Ayano, Y. 1992. Dietary fibre in cereals: nutritional and physiological aspect. *Nippon Eiyo Shokuryo Gakkaishi* (in Japanese) 45: 209-219

Bach Knudsen, K.E. and I. Hansen. 1991. Gastrointestinal implications in pigs of wheat and oat fractions. 1. Digestibility and bulking properties of polysaccharides and other major constituents. *Journal of Nutrition.* 65: 217-232

Becker, W.A., J.V. Spencer, L.W. Mirosh and J.A. Verstrate. 1979. Prediction of fat and fat free liveweight in broiler chickens using backskin fat, abdominal fat and live body weight. *Poultry Science.* 58: 835-842.

Berg, L.R. 1959. Protein, energy and method of feeding as factors in the nutrition of developing White Leghorn pullets. *Poultry Science.* 38: 158-165.

Berg, L.R. and G.E Bearse. 1958. Protein and energy studies with developing White Leghorn pullets. *Poultry Science.* 37: 1340-1346.

Bergner, H., O. Simon and M. Zimeer. 1975. Crude fiber content of the diet as affecting the process of amino acid absorption in rats. *Arch. Anim. Nutr.* 25: 95

Beveridge, R.J.and G.N. Richards. 1975. Investigation of the digestion of spear grass and cotton cellulose by viscometry and by x-ray difraction. *Carbohydrate Research.* 43: 163-172

REFERENCES

Acar, N., F.G. Sizemore, G.R. Leach, R.F. Wideman, R.L. Owen and G.F.Barbato. 1995. Growth of broiler chickens in response to feed restriction regimens to reduce ascites. *Poultry Science.* 74: 833-843.

Adams ,O.L. and E.C. Nabler. 1969. Effect of physical and chemical treatment of grains on growth of and feed utilisation by the chick. 2. Effect of water and acid treatments of grains and grain components on chick growth, nitrogen retention and energy utilisation. *Poultry Science* 48: 922-928

Annison, G. 1990. Polysaccharide composition of Australian wheats and the digestibility of their starches in broiler chicken diets. *Australian Journal of Experimental Agriculture.* 30: 183-186

Annison, G. and M. Choct. 1991. Anti-nutritive activities of cereal non-starch polysaccharides in broiler diets and strategies minimising their effects. *World's poultry Science* 47: 232-242

Antoniou, T. and , R.R. Marquardt. 1981. Influence of rye pentosans on the growth of chicks. *Poultry Science* 60: 1898-1904

Antoniou, T.C., R.R. Marquardt, and E. Cansfield. 1981. Isolation, partial characterisation and anti-nutritional activity of a factor (pentosans) in rye grain. *Journal of Agriculture and Food Chemistry.* 29: 1240-1247

Antoniou, T. and , R.R. Marquardt. 1982. The utilisation of rye by growing chicks as influenced by autoclave treatment, water extraction and water soaking. *Poultry Science* 61: 91-102

AOAC. 1998. Official Methods of Analysis (16th Ed.). Assosciation of Official Analytical Chemists, Washington DC.

Arce, J., M. Berger, and C.L Coello.. 1992. Control of ascites syndrome by feed restriction techniques. *Journal of Applied Poultry Research.* 1: 1-5.

Austic, R.E. 1983. The availability of amino acids as an attribute of feeds in: Feed Information and Animal Production. Proceedings of the 2nd Symposium of the INTERNATIONAL NETWORK OF FEED INFORMATION CENTRES. Eds. Robards G.E and R.G. Packman. 175-189

Austic, R.E. and M.C Nesheim. 1970. Role of kidney arginase in variations of the arginine requirements of chicks. Journal of Nutrition. 100: 855

Ayano, Y. 1992. Dietary fibre in cereals: nutritional and physiological aspect. *Nippon Eiyo Shokuryo Gakkaishi* (in Japanese) 45: 209-219

Bach Knudsen, K.E. and I. Hansen. 1991. Gastrointestinal implications in pigs of wheat and oat fractions. 1. Digestibility and bulking properties of polysaccharides and other major constituents. *Journal of Nutrition.* 65: 217-232

Becker, W.A., J.V. Spencer, L.W. Mirosh and J.A. Verstrate. 1979. Prediction of fat and fat free liveweight in broiler chickens using backskin fat, abdominal fat and live body weight. *Poultry Science.* 58: 835-842.

Berg, L.R. 1959. Protein, energy and method of feeding as factors in the nutrition of developing White Leghorn pullets. *Poultry Science.* 38: 158-165.

Berg, L.R. and G.E Bearse. 1958. Protein and energy studies with developing White Leghorn pullets. *Poultry Science.* 37: 1340-1346.

Bergner, H., O. Simon and M. Zimeer. 1975. Crude fiber content of the diet as affecting the process of amino acid absorption in rats. *Arch. Anim. Nutr.* 25: 95

Beveridge, R.J.and G.N. Richards. 1975. Investigation of the digestion of spear grass and cotton cellulose by viscometry and by x-ray difraction. *Carbohydrate Research.* 43: 163-172

Boorman, K.N.and H. Fisher. 1966. The arginine-lysine interaction in the chick. *British Poultry Science.* 7: 39

Brice, R.E. and I.M. Morrison. 1982 The degradation of isolated hemicelluoses and lignin-hemicellulose complexes by cell-free, rumen hemicellulases. *Carbohydrate Research.* 101: 93-100

Buraczewska, L., E. Shulze, J. Gdala, W Grala. 1988. Ileal and total digestibility of NDF and ADF of different feedstuffs in the pig. In: L. Buraczewska, S. Burazewski, B. Pastuczewska, and T. Zebrowska (Ed.) Digestive Physiology in the Pig. Proc. IVth Int. Seminar. p.224. Institute of Animal Physiology and Nutrition, Jabolona, Poland.

Campbell, G.L., H.L. Classen, K.A. Goldsmith. 1983. Effect of fat retention on the rachitogenic effects of rye fed to broiler chicks. *Poultry Science* 62: 2218- 2223

Carew, L.B., J^R., D.T. Hopkins, M.C. Nesheim. 1964. The influence of amount and type of fat on metabolic efficiency of energy utilization by the chick. *Journal of Nutrition.* 83: 300.

Carre', B., L. Derouet and B. Leclerq. 1990. The digestibility of cell-wall polysaccharides from wheat (bran or whole grain), soybean meal, and white lupin meal in cockerels, muscovy ducks and rats. *Poultry Science* 69:623-633

Carre', B. and B. Leclerq. 1985. Digestion of polysaccharides, protein and lipids by adult cockerels fed on diets containing a pectic cell-wall material from white lupin (Lupinus albus) cotyledon. *British Journal of Nutrition.* 54: 669-680

Chapman, M.E., H.D.Chapman, R.F. Wideman, W.E. Huff, A.H. Hacker, N.C. Rath and J.M. Balog. 1995. Does Pulmonary Hypertension Syndrome (Ascites) occur more freequently in broilers medicated with monensin? *Poultry Science.* 74: 1591-1596

Choct, M. and G. Annison. 1990. Anti-nutritive activity of wheat pentosans in poultry diets. *British Poultry Science* 31: 809-819

Church, D.C. and W.G. Pond. 1988. Basic Animal Nutrition and Feeding. John Wiley & Sons. New York

Clarke, R.T.J and Bauchop, T .(eds.). 1977. Microbial ecology of the gut. Academic Press Inc. (London) Ltd; London U.K.

Coey, W.E. and K.L. Robinson. 1954. Some effects of dietary crude fiber on live weight and carcass conformation of pigs. *Journal of Agricultural Science.* 45: 41

Cuvelier, M.E., H. Richard, and C. Berset. 1992. Comparison of the antioxidative activity of some acid-phenols: Structure-activity relationship. *Biosci., Biotechnol., Biochem.* 56: 324-325

Day, R.M. and O.P. Thomas. 1980. Growth depression of chicks fed a crude rye extract containing pectic substances. *Poultry Science.* 59: 2754-2759

DeMuelenaere, H.J.H., M.L. Chen and A.E. Harper 1967. Assessment of factors influencing estimation of lysine availability in cereal products. *Journal of Agricultural and Food Chemistry.* 15: 310-317.

Dintzis, F.R., L.M. Legg, W.L. Deatherage, F.L. Baker, G.E. Inglett, R.A. Jacob, S.J. Reck, J.M. Munoz, .LM. Klevay, H.H. Sandstead and W.C. Shuey. 1979. Human gastrointestinal action on wheat, corn and soy hull bran-preliminary findings. *Cereal Chemistry.* 56: 123-127

Donaldson, W.E., G.F. Combs, and G.L. Romoser. 1956. Studies on energy levels in poultry rations. 1. The effect of calorie-protein ratio of the ration on growth, nutrient utilization and body composition of chicks. *Poultry Science.* 35: 1100-1105

Ebihara, K and M. Takeuchi. 1992. Effects of corn bran hemicellulose and cecectomy on acute ethanol-induced fatty liver in rats. *Biosci., Biotechnol., Biochem.* 56:1508- 1509

Eliasson, E.E. and H.J. Strecker. 1966. Arginase activity during the growth cycle of Chang's liver cells. *Journal of Biological Chemistry*. 241: 5757.

Eraso, F. and R.D. Hartley. 1990. Monomeric and dimeric phenolic constituents of plant cell walls. *Journal of the Science of Food and Agriculture* 51: 163-170

Englyst, H. 1989. Classification and measurement of plant polysaccharides. *Anim. Feed Sci. Technol.* 23: 27.

Ensminger, M.E., J.E. Oldfield and W.W. Heinemann. 1990. Feeding Poultry in Feeds and Nutrition. Ensminger Publishing Company. Clovis, California. USA. 1013, 1270-1511

Fahey, G.C. and F.J.G. Jung. 1989. Phenolic compounds in forages and fibrous feedstuffs. In Toxicants of Plant Origin; CRC Press: Boca Raton, FL.; pp 123-190

Farrell, D.J. 1994. Utilization of rice bran in diets for domestic fowl and ducklings. *World's Poultry Science* 50: 115-131

Feighner, S.D and M.P. Dashkevicz. 1988. Effect of dietary carbohydrates on bacterial cholyltaurine hydrolase in poultry intestinal homogenates. *Applied and Environmental Microbiology* 54: 337-342

Fengler, A.I. and R.R, Marquardt,. 1988. Water-soluble pentosans from rye: II. Effects of the rate of dialysis on the retention of nutrients by the chick. *Cereal Chemistry* 62: 298-302

Fernandez, J.A. and J.N. Jorgensen. 1986. Digestibility and absorption of nutrients as affected by fiber content in the diet of the pig. Quantitative aspects. *Livest. Prod. Sci.* 15: 53

Fincher, G.B. and B.A. Stone, 1974. A water-soluble arabinogalactan peptide from wheat endosperm. *Australian Journal of Biological Science* 27:117-132.

Fincher, G.B. and B.A Stone. 1986. Cell walls and their components in cereal grain technology. *Adv. Cereal Sci Technol.* 8:207-295

Fonnesbeck, P.V., L.E Harris, and L.C Kearl. 1974. Comparative digestion of plant cell walls by animals. Utah Academy Proc. 51: 85-92.

Forbes, E.B. and R.W. Swift. 1944. Assosciative dynamic effects of protein, carbohydrate and fat. *Journal of Nutrition*. 27: 453

Fraga, G.G., V.S. Martino, G.E. Ferraro, J.D. Coussio and A Boveris,. 1987. Flavonoids as antioxidants evaluated by in vitro and in situ liverchemiluminescence. *Biochem. Pharmacol.* 36: 717-720

Fry, S.C. 1983. Feruloylated pectins from thr primary cell wall: their structure and possible functions. *Planta* 157: 111-123

Fulcher, R.G. 1982. Fluorescence microscopy of cereals. *Food Microsctrust* 1:167-175

Fulcher, R.G. and S.I. Wong. 1980. Inside cereals, a fluorescence microchemical view. In Cereals for Food and Beverages: Recent Progress in Chemistry and Technology; Inglett, G.E., Munck L. Eds.; Academic Press: New York, pp 1-26

Gaillard, B.D.E. 1962. The relationship between the cell wall constituents of roughages and the digestibility of the organic matter. *Journal of Agricultural Science* (Camb) 59: 369-373

Gohl, B. 1981. Feed information summaries and nutritive values. In Tropical Feeds. FAO Animal Production and Health series.

Gohl, B., S. Alden, K. Elwinger and S. Thomke. 1978. Influence of barley beta- glucanase on the feeding value of barley for poultry and moisture content of excreta. *British Poultry Science* 19: 41-47

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedures for Agricultural Research. John Wiley & Sons. New York.

Gordon, A.H., J. Lomax, A. Chesson. 1983. Glycosidic linkages of ,legume, grass and cereal straw cell walls before and after extensive degradation by rumen microorganisms. *Journal of the Science of Food and Agriculture* 34: 1341-1350

Graham, H. and P. Aman. 1987. The pig as a model in dietary fiber digestion studies. *Scand. J. Gastroenterol.* 22 (Suppl. 129): 55

Graham, H. and P. Aman. 1991. Nutritional aspects of dietary fibers. *Anim. Feed Sci. Technol.* 32 143

Graham, H., K. Hesselman, and P. Aman. 1985. The influence of wheat bran, whole crop peas, and beet pulp on the digestibility of dietary components in a cereal-based pig feed. In: A. Just, H. Jorgensen and J.A. Fernandez (Ed.) Digestive Physiology in the Pig. Proc. 3rd Int. Seminar, Beretning fra Statens Husdyrbrugsforsog. 580: 195. Copenhagen, Denmark.

Graham, H., K. Hesselman, and P. Aman. 1986. The influence of wheat bran and sugar-beet pulp on the digestibility of dietary components in a cereal-based pig diet. *J. Nutr.* 116:242

Grau, C.R. and M. Kamei. 1950. Amino acid imbalances and the growth requirements for lysine and methionine. *Journal of Nutrition.* 41:89-101.

Griffiths, L., S. Leeson and J.D. Summers. 1978. Studies on abdominal fat with four commercial strains of male broiler chicken. *Poultry Science.* 57: 1198-1203.

Hall, H.T.B. 1977. Diseases and Parasites of Livestock in the Tropics. Longman Group Ltd. 157-158

Hansen, I.K., B.E. Knudsen and B.O. Eggum. 1992. Gastrointestinal implications in the rat of wheat bran, oat bran and pea fiber. *British Journal of Nutrition* 68: 451

Harper, A.E., N.J. Benevenga and R.M. Wohlhueter. 1970. Effects of ingestion of disproportionate amounts of amino acids. *Physiol. Rev.* 50: 449-466

Harper, A.E. and Q.R. Rogers. 1965. Amino acid imbalances. *Proceedings of the Nutrition Society.* 24: 173.

Hartley, R.D. and C.W. Ford. 1989. Phenolic constituents of plant cell walls and wall biodegradibility. In Plant cell wall polymers; Lewis N.G., Plaice M.G., Eds; ACS Symposium Series 399; American Chemical Society: Washington, DC.

Hatfield, R.D. 1989. Structural polysaccharides in forages and their degradability. *Agronomy Journal* 81: 39-46

Herrmann, K. 1976. Flavonols and flavones in food plants: a review. *J. Food Technol.* 11: 433-448

Hesselmann, K. and Aman P. 1986. The effect of beta-glucanase on the utilization of starch and nitrogen by broiler chickens fed on barley of low or high viscosity. *Animal Feed Science and Technology.* 15: 83-93

Hesselmann, K., Elwinger K. and Thomke S. 1982. Influence of increasing levels of beta-glucanase on the productive value of barley diets for broiler chickens. *Animal Feed Technology.* 7:351-358

Humbert, F., G. Salvat, M. Mroin, P. Colin, C. Lahellae and G. Bennejean. 1989. Microbial colonization of the caecal mucosa of specific-pathogen-freechicks and adherence of an adult SPF chicken microflora to the caeca of conventional newly hatched chicks: study by scanning microscopy. *Avian pathology* 18: 4,577, 585, 587-589

Hussein, A.S., A.H. Cantor and T.H. Johnson. 1986. Relationship of dietary aluminium, phosphorus and calcium to phosphorus and calcium metabolism of broiler chick. *Poultry Science* 65: 62

Ikeda, K. and K. Kusano. 1983. In vitro inhibition of digestive enzymes by indigestible polysaccharides. *Cereal Chemistry* 60: 260-263

Ikegami, S., F. Tsuchihashi. H. Harada, N. Tsuchihashi, E. Nishide and S. Innami. 1990. Effect of viscous indigestible polysaccharides on pancreatic-biliary secretion and digestive organs in rats. *J. Nutr.* 120: 353

Irving, W.W., R.G. Fulcher, M.Bean and R.M. Saunders. 1989. Differentiation of wheat based on fluorescence, hardness, and protein. *Cereal Chemistry* 66 (6): 471- 477

Jacobs, L.R. and J.R. Lupton. 1984. Effect of dietary fiber on rat bowel mucosal growth and cell proliferation. *American Journal of Physiology* 246: G378

Jin, L. 1992. Modulation of feed intake by weanling pigs. Ph. D. Dissertation. North Dakota State University, Fargo

Johansen, H.N., P.J. Wood and K.E. Bach Knudsen. 1993. Molecular weight changes in the (1-3)(1-4)-beta-D-Glucan of Oats incurred by the digestive processes in the upper gastrointestinal tract of pigs. *Journal of Agriculture and Food Chemistry.* 41: 2347-2352

Jones, J.D. 1964. Lysine-arginine antagonism in the chick. *Journal of Nutrition.* 84:313

Julian, R.J. 1993. Ascites in Poultry. *Avian Pathology.* 22:419-454.

Kato, Y. and D.J Nevins. 1985. Isolation and identification of 2-O-(5'-O-trans-feruloyl- beta-L-arabinofuranosyl)-(1-3)-O-beta-D xylopyranosyl-(1-4)-D-xylopyranose as a component of Zea shoot cell walls. *Carbohydr. Res.* 137:139-150

Kelly, D.F., V.M. Lucke, and C.J. Gaskell. 1982. Notes on Pathology for Small Animal Clinicians. John Wright & Sons Ltd, Bristol. England.

Kling, J.G. 1991. Morphology and growth of maize. INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE. p. 9.

Koch, H.P. and E. LOFFLER. 1985. Efficacy of individual flavonoids on lipid peroxidation in human platelets. Methods Find. *Exp. Clin. Pharmacol.* 1: 13-18.

Kuhnau, J. 1976. The flavonoids. A class of semi-essential food components: their role in human nutrition. *World Rev. Nutr. Diet.* 24: 117-191.

Kratzer, F.H., L. Earl. and C. Chiaravanant. 1974. Factors influencing the feeding value of rice bran for chickens. *Poultry Science.* 53:1795-1800.

Larson, R.A. 1988. The antioxidants of higher plant. *Phytochemistry.* 27: 969-978

Leong, K.C., M.L. Sunde, H.R. Bird and C.A. Elvehjem. 1959. Interrelationships among dietary energy, protein and amino acids for chickens. *Poultry Science.* 38:1267-1285.

Little, T.M. and J.F. Hills. 1978. Agricultural experimentation, design and analysis. John Wiley & Sons. New York.

Longland, A.C., W.H. Close and A.G. Low. 1988. Contribution of carbohydrate fermentation to energy balance in pigs. In: L. Burazewska, S. Burazewska, B Pastuzewska, and T. Zebrowska (Ed.) Digestive physiology in the pig. Proc. IVth Int. Seminar. p.108. Institute of Animal Physiology and Nutrition, Jablonna, Poland.

Low, A.G. 1982. Digestibility and availability of amino acids from feedstuffs for pigs: a review. *Livest Prod. Sci.* 9: 511

Low, A.G. 1985. Role of dietary fiber in pigs diet. In: W. Harresign (Ed.) Recent Advances in Nutrition. p.87. Butterworths, London.

Low, A.G. 1989. Secretory response of the pig gut to non-starch polysaccharides. *Anim. Feed Sci Technol.* 23: 55

MacArthur, L.A. and B.L. D'Appolonia. 1980. Comparison of the non-starch polysaccharides in oats and wheats. *Cereal Chemistry* 57:39-45

MacAuliffe, T. and J. McGinnis. 1971. Effect of antibiotic supplements to diets containing rye on chick growth. *Poultry Science.* 50: 1130-1134

Martin, E.A. and Farrell D.J. 1993. The beneficial effects of a microbial phytase in rice bran based diets. Proceedings of Australian Poultry Science Symposium, University of Sydney, 1993, p. 74

Martin-Tanguy, J., E. Perdrizet, J. Prevost and C. Martin. 1982 Hydroxycinnamic acid amides in fertile and cytoplasmic sterile lines of maize. *Phytochemistry* 21: 1939-1945

McBurney, M.I. and Thompson L.U. 1990 Fermentative characteristics of cereal brans and vegetable fibres. *Nutr. Cancer*, 13: 271-280

McNab, J.M. 1973. The avian caeca: a review. *World's Poultry Science Journal.* 29: 251-263

Microsoft Excel Program. 1995. Microsoft Corporation, Santa Rosa, California, USA.
Misir, R. and R.R. Marquardt. 1978. Factors affecting rye (Secale cereale L.) utilization in growing chicks. I. The influence of rye level, ergot and penicillin supplementation. *Canadian Journal of Animal Science* 58: 691-701
Miyasaka, H., H. Sanada and Y. Ayano. 1992. Relationship between colonic products from corn bran hemicellulose and the lipid metabolism in rats fed on diets supplemented with orotic acid. *Biosci., Biotechnol., Biochem.* 56: 157-158
Mongeau, R., H.S. Yiu and R. Brassard. 1991. Chemical fluorescence microscopic analysis of fiber degradation of oat, hard red spring wheat, and corn bran in rats. *Journal of Agriculture and Food Chemistry* 39: 1966-1971
Moran, E.T. J^{R}., S.P. Lall and J.D. Summers. 1969. The feeding values of rye for the growing chick: effect of enzyme supplements, antibiotics, autoclaving and geographical area of poultry production. *Poultry Science* 48: 939-949
Nahm, K.H., Carlson C.W. 1985. Effects of cellulase from Trichorderma viride on nutrient utilization by broilers. *Poultry Science* 64: 1536-1540
Nesheim, M.C. 1968. Kidney Arginase activity and lysine tolerance in strains of chickens selected for a high or low requirement of arginine, *Journal of Nutrition*. 95: 79.
Nielsen, S.S. 1994. Chemical Analysis of Foods. Chapman and Hall, New York, NY.
Nyman, M. T.F. Schweizer, S.Tyren, S. Reimann and G. Aspn. 1990 Fermentation of vegetable in the intestinal tract of rats and effects on fecal bulking and bile acid excretion. *Journal of Nutrition* 120: 459-466
Oberleas, D., M.E. Muhrer and B.L. O'Dell. 1966 The availability of Zinc from foodstuffs in "Zinc Metabolism", Eds A.S. Prasad, C.C. Thomas, Springfield, Illinois. Chapter 13.
Ohta, T., S.Yamasaki, Y. Egashira and H. Sanada. 1994. Antioxidative activity of corn bran hemicellulose fragments. *Journal of Agriculture and Food Chemistry* 42: 653-656
Olson, A.C., G.M. Gray, M.C. Csiu and S.E. Fleming. Cellulose, xylan, corn bran, and pectin in the human digestive process. In Unconventional sources of dietary fiber. Physiological and in vitro functional properties; Furda, I., Ed.; ACS Symposium Series 214; American Chemical Society: Washington, DC.
Onyeneho, S.N. and N.S. Hettiarachchy. 1992. Antioxidative activity of Durum wheat bran. *Journal of Agriculture and Food Chemistry*. 40:1496-1500
Perlin, A.S. 1952. Isolation and comparison of the soluble pentosans of wheat flour. *Cereal Chemistry*. 28:370-381
Portman, O.W., G.V. Mann and A.P. Wysocki. 1985. Bile acid excretion by the rat: Nutritional effects. *Arch. Biochem. Biophys.* 58: 224
Potkins, Z.V., T.L.J. Lawrence and R.J. Thomlinson. 1991. Effects on ileal apparent digestibility in the growing pig of replacing barley with bran, oatmeal by- product, guar gum and pectin. *Anim. Feed Sci. Technol.* 35: 171
Powell, T.S. and M.S. Gehle. 1974. Effect of different feeding regimes on performance of color sexed broilers , sexes reared separate. *Nutr. Rep. Int.* 10: 333-337
Preece, I.A.and K.G. Mackenzie. 1952. Non-starchy polysaccharides of cereal grains. I. Fractionation of the barley gums. *Journal of the Institute of Brewing* 58: 352-362
Pussayanawin, V. and D.L. Wetzel D.L. 1987. High performance liquid chromatographic determination of ferulic acid in wheat milling fractions as a measure of bran contamination. *J. Chromatogr.* 391: 243-255
Pussayanawin, V., D.L. Wetzel and R.G. Fulcher. 1988. Fluorescence detection and measurement of ferulic acid in wheat milling fractions by microscopy and HPLC. *Journal of Agriculture and Food Chemistry* 36: 515-520

Reiners, R.A. and C.M. Gooding. 1970. Corn oil. In: G.E. Inglett (ed) Corn: culture, processing, products. The AVI Publishing Co., Westport, Conn.

Rerat, A. 1985. Intestinal absorption of end products from digestion of carbohydrates and proteins in the pig. *Arch. Anim. Nutr.* 35: 461.

Rogers, Q.R., R.I. Thomas and A.E. Harper. 1967. Effect of excess leucine on growth and food selection. *Journal of Nutrition.* 91:561.

Saini, J.S. and R.J. Henry. 1989. Fractionation and evaluation of pentosans: comparisons with wheat and rye. *Cereal Chemistry* 66: 11-14

Saito, M., I. Tasaki, K. Kibe, H. Yamada and T. Igaraski. 1959. Effect of various cellulose levels in the diet on chick growth. *Poultry Science* 38: 373-376

Sauer, W.C., R. Mosentin and F. Ahrens den Hartog. 1991. The effect of source of fiber onthe ileal and fecal amino acid digestibility and bacterial nitrogen excretion in growing pigs. *J. Anim. Sci.* 69: 4070.

Sauer, W.C. and L. Ozimek. 1986. Digestibility of amino acids in swine: Results and practical application. A review. *Livest. Prod. Sci.* 15: 376

Saunders, R.M. 1986. Rice bran composition and potential food uses. *Food Reviews International* 1: 465-495

Scott, M.L., G.F. Heuser, and L.C. Norris. 1948. Energy-protein and unidentified vitamins in poult nutrition. *Poultry Science.* 27: 773-780

Scott, M.L., M.C. Nesheim and J.R. Young. 1982. Nutrition of the Chicken. M.L. Scott and Assosciates. New York.

Sen, A., D. Bergvinson, S.S. Miller, J. Atkinson , G. Fulcher and J.T. Arnason. 1994. Distribution and michrochemical detection of phenolic acids, flavonoids, and phenolic acid amides in maize kernels. *Journal of Agriculture and Food Chemistry* 42: 1879-1883

Shafey, T.M. and M.W. Mcdonald. 1990. Effects of dietary calcium:available phosphorus ratio on calcium tolerance of broiler chickens. *Australian Journal of Experimental Agriculture* 30: 483-90.

Shlosberg, A., E. Berman, U. Bendheim, and I. Plavnik. 1991. Controlled early feed restriction as a potential means of reducing incidence of ascites in broilers. *Avian Dis.* 35: 681-684.

Shulze, H., P. Van Leeuwen, M.W.A. Verstegen, J. Huisman, W.B. Souffrant and F. Ahrens. 1994. Effect of level of dietary neutral detergent fiber on ileal apparent digestibility and ileal nitrogen losses in pigs. *J. Anim. Sc.* 72: 2362-2368.

Shutte, J.B. 1990. Nutritional implications and metabolizable energy value of D-xylose and L-arabinose in chicks. *Poultry Science* 69: 1724-1730

Sibbald, I.R., S.J. Slinger and G.C. Ashton. 1961. Factors affecting the metabolizable energy content of poultry feeds. 2. Variability in the ME values attributed to tallow and undegummed soybean oil. *Poultry Science.* 40: 303-308.

Singleton, V.L., 1981. Naturally occuring food toxicants: phenolic substances of plant origin common in foods. *Adv. Food Res.* 27: 149-242.

Sircar, B., L.R. Johnson and L.M. Litchenberger. 1983. Effects of synthetic diets on gastrointestinal mucosal DNA synthesis in rats. *Am. J. Physiol.* 244: G327

Smith, G.H. and D. Lewis. 1966. Arginine in poultry nutrition. 3. Agent and target in amino acid interactions. *British Journal of Nutrition.* 20: 621.

Smith, H. and J.H. Taylor. 1961. Effect of feeding two levels of dietary calcium on the growth of broiler chickens. *Nutrition Abstract* 32:1200

Smith, O.B. and E. Kabaija.. 1985. Effect of high dietary calcium and wide calcium-phosphorus ratios in broiler diets. *Poultry Science* 64:1713-20.

Smith, R.E. 1968. Effect of arginine upon the toxicity of excesses of single amino acids in chicks. *Journal of Nutrition.* 95: 547.

Snedecor, G.W. and W. G. Cochran. 1989. Statistical methods. Iowa State University Press, Ames Iowa 50014.

Snetsinger, D.C. and H.M. Scott. 1961. Efficacy of glycine in alleviating the stress induced by dietary excesses of single amino acids in chicks. *Poultry Science.* 40:1675.

Soltes, E.J. 1983. Cellulose: Elusive component of the plant cell wall. p.271-298. In W.A. Cote (ed) Biomass utilization. Plenum Press.New York.

Sonaiya, E.B. 1985. Abdominal fat weight and thickness as predictors of total body fat in broilers. *British Poultry Science.* 26: 453-458.

Souffrant, W.B. and F. Ahrens. 1994. Effect of level of dietary neutral detergent fiber on ileal apparent digestibility and ileal nitrogen losses in pigs. *J. Anim. Sci.* 72: 2362

Southgate, D.A.T. 1990. Dietary fiber and health. In: D.A.T. Southgate (ed.) Dietary Fiber: Chemical and Biochemical aspects. Royal Soc. Chem. p. 10 Cambridge, U.K.

Statistical Program for Social Sciences. 1997. Statistical Program for Social Sciences Inc. Chicago Illinois. 60606.

Sunde, M.L. 1956. A relationship between protein level and energy level in chick rations. *Poultry Science.* 35: 350-354.

Suttle, N.F. 1983. The availability of amino acids as an attribute of feeds in: Feed Information and Animal Production. Proceedings of the 2nd Symposium of the INTERNATIONAL NETWORK OF FEED INFORMATION CENTRES. Eds. Robards G.E and R.G. Packman. 211-237.

Thomas, C. and G.W. Richter. 1984 Sandritter's Color Atlas and Textbook of Histopathology. Year Book Medical Publishers. 1-3.

Thomas, O.P. and G.F. Combs. 1967. Relationship between serum protein level and body composition in the chick. *Journal of Nutrition.* 91:468-472.

Titgemeyer, E.C., L.D. Bourquin, G.C. Fahey Jr., K.A. Garleb. 1991. Fermentability of various fiber sources by human fecal bacteria in vitro. *Am. J. Clin Nutr.* 53: 1418

UNZA Vet. Med. 1990. Manual of Histopathological Sections. Department of Paraclinical Studies, Pathology Laboratory. School of Veterinary Medicine. University of Zambia. 1-10.

Van Soest, P.J. 1981. Limiting factors in plant residues of low biodegradability . *Agric. Environ.* 6:135-143

Van Soest, P.J. 1982. Nutritional Ecology of the Ruminant. Cornell University Press. New York.

Vahouny, G.V. and M.M. Cassidy. 1985. Dietary fiber and absorption of nutrients. *Proc. Soc. Exp. Biol. Med.* 180: 432

Vohra, P., G. Shariff, F.H. Kratzer. 1979. Growth inhibitory effect of some gums and pectin for Tribolium castaneum larvae, chickens and Japanese quail. *Nutr Rep. Int.* 19:463-467

Vondell, R.M. and Ringrose R.C. 1958. The effect of protein and fat levels and calorie to protein ratio upon the performance of broilers. *Poultry Science.* 37: 147-151.

Wagner, D.D.and O.P. Thomas. 1977. A rye type growth depression of chicks fed pectin. *Poultry Science* 56: 615-619

Ward, A.T. and R.R. Marquardt. 1987. Anti-nutritional activity of a water soluble pentosan- rich fraction from rye grain. *Poultry Science* 66: 1665-1674

Warren, B.E. and D.J. Farrell. 1991. The nutritive value of full-fat and defatted Australian rice bran. V. The apparent retention of minerals and apparent digestibility of amino acids in chickens and adult cockerels fitted with ileal cannulae. *Animal Feed Science and Technolgy* 34: 323-342

Weber, E.J. 1973. Structure and composition of cereal components as related to their potential industrial utilisation. IV. Lipids. Symposium proceedings on Industrial uses of Cereals. American Assosciation of Cereal Chemists. 161-206.

White, W.B. H.R. Birb, M.L. Sunde and J.A. Marlett. 1981. The viscosity interaction of barley beta-glucan with Trichoderma viride cellulase in the chick intestine. Poultry Science 60: 1043-1048

Wideman, R.F. and W.G. Bottje. 1993. Current understanding of the ascites syndrome and future research directions. Nutrition and Technical Symposium Proceedings. Novus International, Inc., St Lois MO.

Wilgus, H.S. J[R] 1931. The quantitative requirement of the growing chick for calcium and phosphorus. *Poultry Science.* 10: 107

APPENDICES.

APPENDIX A: NUTRIENT CONTENT OF INGREDIENTS AND TREATMENT FORMULATIONS

A i): Nutrient content of ingredients used in Feed Formulations

INGREDIENT	@NUTRIENT CONTENT (%)						
	DM	EE	CP	Ca*	P$	Lysine	Methionine
Maize meal[1]	84.5	3.8	6.56	0.4	0.27	2.0	0.10
Maize meal[2]	88.5	4.4	8.75	0.4	0.3	2.0	0.10
Soyabean Meal[1]	88.0	2.4	45.65	0.8	0.65	2.3	0.46
Soyabean Meal[2]	–	2.2	48.6	–	–	2.3	0.46
DCP	–	–	–	13.2	15.35	–	–
LSM	–	–	–	32.4	–	–	–
Lysine	–	–	–	–	–	0.99	–
Met	–	–	–	–	–	–	0.99
Maize Bran[2]	89.4	8.8	10.39	0.2	0.3	–	–

@ as determined by chemical analyses of Appendix B., except for lysine and methionine values which were obtained from Ensminger et al. (1990).

* Ca in plants unavailable to poultry (Ensminger et al., 1990)

$ P in plants is 1/3 available to poultry (Ensminger et al., 1990)

1 Ingredient used in pre-starter and starter formulations.

2 Ingredient used in finisher formulations.

A ii): Nutrient content of treatment formulations (As determined in Chemical Analyses)

BRAN LEVEL %	DM %	CP %	EE %	NDF %	Ca %	P %	GE k cal/kg
0	90.44	18.51	3.80	18.65	1.01	0.49	4.235
10	89.97	17.61	4.60	22.55	1.00	0.49	4.411
20	90.06	17.90	5.20	24.15	0.97	0.59	4.563
30	90.33	15.53	5.37	27.95	0.92	0.54	4.643

APPENDIX B: CHEMICAL ANALYSIS PROCEDURES

B i) DRY MATTER ANALYSIS (According to AOAC, 1998)

Samples weighing approximately 2 g were placed in pre-weighed aluminium dishes with covers. The covers were loosened and the dishes were placed in a Memmert oven (Model 500, Memmert Company, Schwabach, Germany) at 110 ^{0}C for 2 hours. The dishes were removed from the oven and the lids tightened. The dishes were left to cool in a dessicator for 30 minutes and then they were weighed. The difference between the weight before and after drying was the water evaporated. This was subtracted from the weight of the pre-drying sample to give the weight of DM in the sample. DM percentage in the sample was calculated as:

$$\frac{\text{Weight of dry matter}}{\text{Weight of air-dry sample}} \times 100 = \%DM$$

B ii) CRUDE PROTEIN ANALYSIS (According to AOAC, 1998)

Samples weighing approximately 2 g were digested in 24 ml concentrated sulphuric acid in a Foss Tecator Digestion System (Foss Tecator Company, Hoganas, Sweden) at 420 ^{0}C for 1 hour. 8 g of a mixture of catalyst made by 400 g potassium sulphate, 16 g copper sulphate and 3 g selenium powders was added to speed up the digestion. All the organic matter was digested. The digested solution, containing ammonium sulphate (produced from the reaction between nitrogen in the sample and sulphuric acid) was diluted to 250 ml. 5 ml of the diluted solution was pippetted into a Markham semi-micro Kjeldahl distillation apparatus. 10 ml (or excess) of a 40% sodium hydroxide solution was added to release the ammonia from ammonium sulphate into the ionized ammonium form. The ammonia was distilled into a 1% boric acid indicator solution (indicator was a mixture of 2 parts 0.2% methyl red and 3 parts 0.2% bromocresol green). The solution was green. A 0.1M solution of hydrochloric acid (Hcl) was used to titrate the ammonia, the end point giving a purplish colour (due to indicator). CP percentage in the sample was calculated as:

$$\frac{0.00014 \times \text{vol Hcl} \times 250 \times 6.25}{\text{Weight of air dry sample} \times 5} \times 100 = \%CP$$

where: 1 ml of 0.1M Hcl = 0.00014 g nitrogen

vol Hcl = Volume Hcl used in titration

$\frac{250}{5}$ = Dilution rate

6.25 = Conversion factor for organic nitrogen to crude protein

The result of the analysis represents the crude protein content of the sample because nitrogen also comes from nonprotein components such as free amino acids, small peptides, nucleic acids, phospholipids, amino sugars, porphyrin, some vitamins, uric acid, and ammonium ions *(Nielsen,1994)*

B iii) ETHER EXTRACT ANALYSIS (According to AOAC 1998).

Samples weighing approximately 5 g were placed in extraction thimbles. The cotton wool plugged thimbles were placed in reflux condensers attached to pre-weighed soxhlet flasks containing petroleum ether with a boiling range of 60-80 ^{0}C The process involved extraction of the sample using hot condensed petroleum ether in a semi-continuous manner for 8 hours (9 hours for faecal samples). The ether extract always remained in the soxhlet flask. After evaporation of the petroleum ether, the oil and flask were weighed. The gain in weight was reported as weight of oil or extract. EE percentage of the sample was calculated as:

$$\frac{\text{Wt of Oil}}{\text{Weight of air dry sample}} \times 100 = \%EE$$

The EE represents the crude fat content of the sample and may be a mixture of simple, compound, and derived lipids. Proteins, amino acids and carbohydrates may also be extracted in EE *(Nielsen, 1994)*. It is possible for these non-lipid components to have been extracted in this analysis since the solvent that was used (petroleum ether) has a higher boiling point than the usually recommended solvent (diethyl ether) which has a much lower boiling point of 34.6 ^{0}C *(Nielsen, 1994)*.

B iv) DETERMINATION OF ASH AND MINERAL EXTRACTION (According to AOAC, 1998)

Samples weighing approximately 2 g were placed in pre-weighed porcelain crucibles and placed in a Nabertherm muffle furnace (Nabertherm Company, West Germany) to ash at 550 ^{0}C. After 4 hours the crucibles were removed from the furnace and left to cool in a dessicator for 30 minutes. The difference in weight between the empty crucible and the crucible with ash was reported as ash content of the sample. Percentage of ash in the sample was calculated as:

$$\frac{\text{Weight of ash}}{\text{Weight of air dry sample}} \times 100 = \%\text{ash}$$

The ash was used to determine Ca and P content of the sample. The minerals in the ash were first extracted by boiling ash in 10 ml 2 N Hydrochloric acid. The solution was then filtered out into a 100 ml flask and made up to the mark by washing the residue with hot distilled water.

B v) DETERMINATION OF CALCIUM (According to AOAC, 1998)

50 ml of the mineral extracts in Section B iv were pippetted into 400 ml beakers and 100 ml of hot distilled water added. 5 drops of methyl red indicator were added to each solution which was then brought to boiling. Approximately 1 g powdered ammonium oxalate was added to the solution to precipitate the calcium in the solution as calcium oxalate. The precipitate was filtered after being allowed to set for 2 hours. The calcium oxalate residue was dissolved in 20 ml 2 N sulphuric acid. After diluting with 100 ml hot water, the solution was titrated to faint pink with N/10 potassium permanganate. Percentage Ca in the sample was calculated as:

$$\frac{0.002 \times \text{vol Potassium permanganate}}{\text{Weight of air dry sample}} \times 100 = \%\text{Ca}$$

where: 1 ml $\frac{N}{10}$ potassium permanganate = 0.002 g Ca

vol Potassium permanganate = Volume of potassium permanganate used

B vi) DETERMINATION OF PHOSPHORUS (According to AOAC, 1998)

The mineral extracts from Section B iv were further diluted by a factor of 20. This was done by pipetting 2.5 ml of each sample's mineral extract into a 50 ml volumertric flask and making up to the mark with distilled water. The purpose of the dilution was to obtain solutions with P concentrations whose optical density, when the colors were developed, could be read by a colorimeter at 660 nm wavelength.

Color development was achieved by adding 4 ml acid molybdate and then 3ml amino naptholsulphonic acid (ANSA) to 1 ml of sample solution in a test tube. A compound which is supposed to have the formula $(MoO_2, {}_4MoO_3)_2$. H_3PO_4 is developed by adding acid molybdate to an orthophosphate. The phospomolybdate produced is reduced by ANSA to give a blue colored compound (Egan et al., 1981). The test tubes were left to stand for 20 minutes to allow the color to develop. The solutions were then put in 15 mm diameter cells and optical density read at 660 nm.

A standard curve was used to determine the concentration of the sample solutions. The standard solutions used to produce the standard curve had concentrations of 1 mg, 2 mg, 3 mg, 4 mg and 5 mg P per 100 ml. The solutions were made by diluting 1 ml, 2 ml, 3 ml, 4 ml and 5 ml of a 1 mg P per ml standard stock solution of potassium dihydrogen phosphate in 100 ml of distilled water. Color was developed for the standard solutions as for the sample solutions by adding 4 ml acid molybdate and 3 ml ANSA to 1 ml of standard solution in a test tube and leaving for 20 minutes. Optical density of the standard solutions was also read at 660 nm.

Percentage of P in the sample was calculated as:

$$\frac{\text{mg P/100 ml} \times 20}{10 \times \text{weight of air dry sample}} = \%P$$

where: mg P/100 ml was obtained from standard curve

20 = dilution factor for mineral extract solution obtained from 100 ml solution

10 = dilution factor for ash in 2 N hydrochloric acid.

B vii) DETERMINATION OF NEUTRAL DETERGENT FIBRE (According to Van Soest, 1982)

0.35 g samples were boiled for an hour in 35 mls of sodium laural sulphate in 50 ml taylor tubes. The detergent extracts lipids, sugars, organic acids, and other water soluble material, pectin, non-protein nitrogenous compounds, soluble protein and some of the silica and tannin (Church and Pond, 1988). The non- soluble material containing cellulose, hemicellulose, lignin, some protein, bound nitrogen, minerals and cuticle was extracted by filtering the taylor tube contents on porous glass crucibles, connected via a trap to a vacuum pump. The residue was rinsed with hot water and after removal of most of the free water by suction, the crucibles were placed in a Memmert oven (Model 500, Memmert Company, Schwabach, Germany) to dry at 110 ^{0}C for 2 hours. After cooling in a dessicator for 30 minutes, the crucibles and dry residue were weighed. The dry residue was then ashed in a Nabertherm muffle furnace (Nabertherm Company, West Germany)at 550 ^{0}C for 4 hours. The crucibles and ash were again cooled in a dessicator for 30 minutes and then weighed. Percentage NDF in the sample was calculated as:

$$\frac{\text{Loss in weight from ashing}}{\text{Weight of air dry sample}} \times 100 = \%\text{NDF}$$

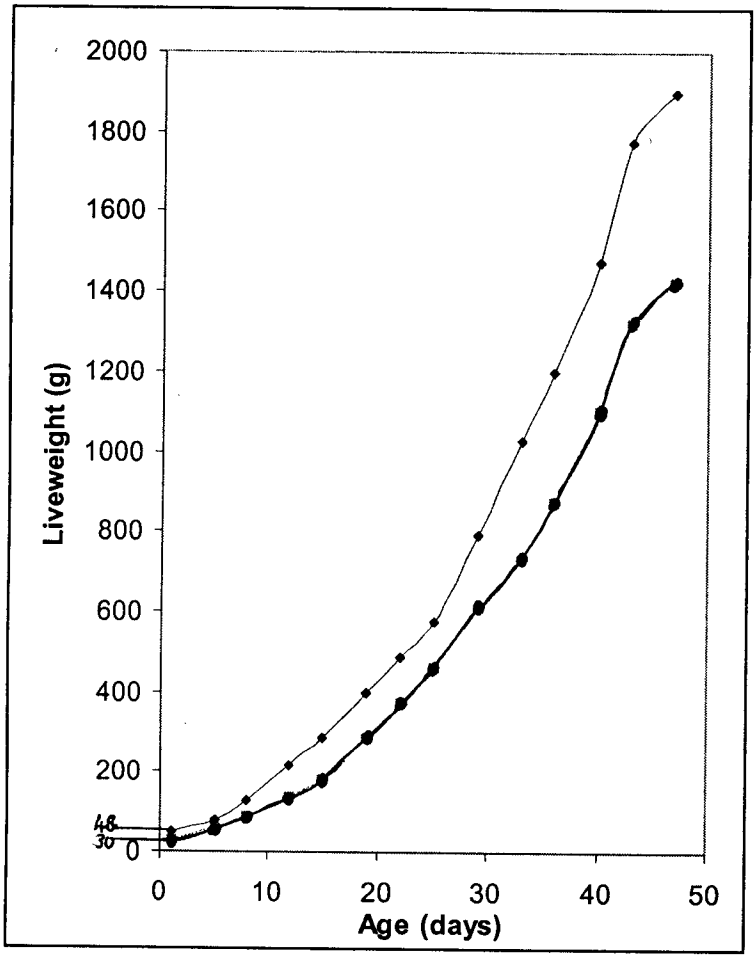
B viii) DETERMINATION OF GROSS ENERGY (According to AOAC, 1998)

Approximately 1/2 inch diameter pellets were made from the samples and weighed. The weighed pellets were placed in combustion capsules. The combustion capsules, with sample pellets in them, were placed singly in the combustion capsule holder of a Parr adiabatic bomb calorimeter (Elkay Manufacturing Company, Lanark, Illinois, USA) 10 cm of fuse wire was attached to connect power leads into the bomb. The fuse wire was made into a loop which touched the sample pellet to ignite it when power was passed through the fuse wire. The bomb head was replaced and securely closed. After oxygen at 20 atmospheres was introduced into the bomb it was placed in the calorimeter's oval bucket which contained 2000 ml tap water at 24-27 ^{0}C. Electric firing wires were attached to leads into the bomb. The lid to the calorimeter was replaced and the temperature in the inner and outer jacket allowed to equilibrate. After firing the sample, the temperature was allowed to rise to a constant temperature which was within 0.1 ^{0}C for both the inside and outside jacket.

The bomb was dismantled and inside washed with distilled water. The washings represented heat generated by a chemical reaction in the bomb and was not due to the sample burning). Washings were titrated with sodium carbonate solution after 5 drops of methyl orange were added to them, up to a straw coloured end point. The unburnt fuse wire was measured.
Gross energy of the sample was calculated as:

$$\frac{\text{Rise in temp. x Calorimeter heat capacity (k cals/g)}}{\text{Weight of sample}} - \text{washings heat} - \text{burnt fuse wire heat}$$

APPENDIX C: LINE GRAPHS FOR MEAN LIVEWEIGHTS FOR ARBOR ACRES AND COBB 500 WITH AGE IN DAYS



Arbor acres

Cobb 500

APPENDIX D: ANALYSIS OF VARIANCE (ANOVA) TABLES

D i) ANOVA table for liveweight (kg) at 43 days

Source	df	MS	F Value	Probability
Blocks	2	0.013	3.0520	0.0622
Strain	1	2.477	560.8130	0.0000
Starting date for bran feeding	1	0.001	0.2060	NS
Strain x Starting date	1	0.004	0.8840	NS
Bran levels	3	0.002	0.3869	NS
Strain x Bran levels	3	0.001	0.1514	NS
Starting date x Bran levels	3	0.005	1.1882	NS
Strain x starting date x Bran levels	3	0.002	0.4316	NS
Error	30	0.004		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (kg)
Block	1	1.568a
	2	1.563a
	3	1.515b
Strain	Arbor acres	1.776a
	Cobb	1.322b
Starting date	Day 29	1.553
	Day 35	1.544
Bran level	0%	1.547
	10%	1.538
	20%	1.566
	30%	1.545

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (kg)
Strain x Starting date	*Arbor acres*	*Day 29*	-	*1.771*
	Arbor acres	Day 35	-	1.781
	Cobb	Day 29	-	1.335
	Cobb	Day 35	-	1.308
Strain x Bran level	Arbor acres	-	0%	1.784
	Arbor acres	-	10%	1.762
	Arbor acres	-	20%	1.785
	Arbor acres	-	30%	1.773
	Cobb	-	0%	1.310
	Cobb	-	10%	1.313
	Cobb	-	20%	1.346
	Cobb	-	30%	1.317
Starting date x Bran level	-	Day 29	0%	1.547
	-	Day 29	10%	1.560
	-	Day 29	20%	1.542
	-	Day 29	30%	1.563
	-	Day 35	0%	1.547
	-	Day 35	10%	1.515
	-	Day 35	20%	1.589
	-	Day 35	30%	1.526

Dii) ANOVA table for feed consumption (kg) at 43 days

Source	df	MS	F Value	Probability
Blocks	2	0.100	4.4977	0.0196
Strain	1	4.245	190.5829	0.0000
Starting date for bran feeding	1	0.007	0.3267	NS
Strain x Starting date	1	0.008	0.3378	NS
Bran levels	3	0.047	2.0909	NS
Strain x Bran levels	3	0.002	0.0919	NS
Starting date x Bran levels	3	0.003	0.1386	NS
Strain x starting date x Bran levels	3	0.021	9.226	NS
Error	30	0.022		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (kg)
Block	1	2.814b
	2	2.858b
	3	2.967a
Strain	Arbor acres	3.177a
	Cobb	2.582b
Starting date	Day 29	2.892
	Day 35	2.867
Bran level	0%	2.885
	10%	2.923
	20%	2.921
	30%	2.790

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (kg)
Strain x Starting date	Arbor acres	Day 29	-	3.177
	Arbor acres	Day 35	-	3.177
	Cobb	Day 29	-	3.607
	Cobb	Day 35	-	2.558
Strain x Bran level	Arbor acres	-	0%	3.170
	Arbor acres	-	10%	3.238
	Arbor acres	-	20%	3.217
	Arbor acres	-	30%	3.084
	Cobb	-	0%	2.601
	Cobb	-	10%	2.607
	Cobb	-	20%	2.626
	Cobb	-	30%	2.496
Starting date x Bran level	-	Day 29	0%	2.885
	-	Day 29	10%	2.922
	-	Day 29	20%	2.937
	-	Day 29	30%	2.823
	-	Day 35	0%	2.885
	-	Day 35	10%	2.923
	-	Day 35	20%	2.905
	-	Day 35	30%	2.757

Diii) ANOVA table for feed conversion ratio at 43 days

Source	df	MS	F Value	Probability
Blocks	2	0.152	8.4718	0.0012
Strain	1	0.343	19.0870	0.0001
Starting date for bran feeding	1	0.000	0.0035	NS
Strain x Starting date	1	0.000	0.0230	NS
Bran levels	3	0.020	1.1315	NS
Strain x Bran levels	3	0.004	0.2379	NS
Starting date x Bran levels	3	0.012	0.6533	NS
Strain x starting date x Bran levels	3	0.009	0.4805	NS
Error	30	0.018		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean
Block	1	1.803b
	2	1.836b
	3	1.986a
Strain	Arbor acres	1.791a
	Cobb	1.960b
Starting date	Day 29	1.876
	Day 35	1.874
Bran level	0%	1.890
	10%	1.916
	20%	1.877
	30%	1.818

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean
Strain x Starting date	Arbor acres	Day 29	-	1.795
	Arbor acres	Day 35	-	1.787
	Cobb	Day 29	-	1.958
	Cobb	Day 35	-	1.962
Strain x Bran level	Arbor acres	-	0%	1.777
	Arbor acres	-	10%	1.842
	Arbor acres	-	20%	1.804
	Arbor acres	-	30%	2.740
	Cobb	-	0%	1.003
	Cobb	-	10%	1.989
	Cobb	-	20%	1.950
	Cobb	-	30%	1.897
Starting date x Bran level	-	Day 29	0%	1.890
	-	Day 29	10%	1.879
	-	Day 29	20%	1.917
	-	Day 29	30%	1.818
	-	Day 35	0%	1.890
	-	Day 35	10%	1.952
	-	Day 35	20%	1.836
	-	Day 35	30%	1.818

D iv) ANOVA table for liveweight at 47 days

Source	df	MS	F Value	Probability
Blocks	*2*	*0.038*	*5.7251*	*0.0078*
Strain	1	2.628	393. 9361	0.0000
Starting date for bran feeding	1	0.001	0.1403	NS
Strain x Starting date	1	0.000	0.0703	NS
Bran levels	3	0.006	0.8517	NS
Strain x Bran levels	3	0.003	0.4452	NS
Starting date x Bran levels	3	0.005	0.7336	NS
Strain x starting date x Bran levels	3	0.002	0.3184	NS
Error	30	0.007		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (kg)
Block	1	1.705a
	2	1.671ab
	3	1.608b
Strain	Arbor acres	1.895a
	Cobb	1.427b
Starting date	Day 29	1.666
	Day 35	1.657
Bran level	0%	1.658
	10%	1.670
	20%	1.685
	30%	1.633

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (kg)
Strain x Starting date	Arbor acres	Day 29	-	1.903
	Arbor acres	Day 35	-	1.888
	Cobb	Day 29	-	1.429
	Cobb	Day 35	-	1.426
Strain x Bran level	Arbor acres	-	0%	1.898
	Arbor acres	-	10%	1.923
	Arbor acres	-	20%	1.910
	Arbor acres	-	30%	1.851
	Cobb	-	0%	1.418
	Cobb	-	10%	1.416
	Cobb	-	20%	1.459
	Cobb	-	30%	1.416
Starting date x Bran level	-	Day 29	0%	1.658
	-	Day 29	10%	1.684
	-	Day 29	20%	1.663
	-	Day 29	30%	1.658
	-	Day 35	0%	1.658
	-	Day 35	10%	1.655
	-	Day 35	20%	1.706
	-	Day 35	30%	1.608

D v) ANOVA table for feed consumption at 47 days

Source	df	MS	F Value	Probability
Blocks	2	0.032	0.5909	NS
Strain	1	5.841	106.4705	0.000
Starting date for bran feeding	1	0.055	0.9942	NS
Strain x Starting date	1	0.105	1.9225	NS
Bran levels	3	0.059	1.0782	NS
Strain x Bran levels	3	0.018	0.3363	NS
Starting date x Bran levels	3	0.016	0.2858	NS
Strain x starting date x Bran levels	3	0.038	0.6928	NS
Error	30	0.055		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (kg)
Block	1	3.300
	2	3.355
	3	3.389
Strain	Arbor acres	3.697a
	Cobb	2.999b
Starting date	Day 29	3.382
	Day 35	3.315
Bran level	0%	3.303
	10%	3.398
	20%	3.418
	30%	3.274

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (kg)
Strain x Starting date	Arbor acres	Day 29	-	3.684
	Arbor acres	Day 35	-	3.710
	Cobb	Day 29	-	3.080
	Cobb	Day 35	-	2.919
Strain x Bran level	Arbor acres	-	0%	3.697
	Arbor acres	-	10%	3.762
	Arbor acres	-	20%	3.754
	Arbor acres	-	30%	3.576
	Cobb	-	0%	2.909
	Cobb	-	10%	3.034
	Cobb	-	20%	3.082
	Cobb	-	30%	2.972
Starting date x Bran level	-	Day 29	0%	3.386
	-	Day 29	10%	3.400
	-	Day 29	20%	3.431
	-	Day 29	30%	3.311
	-	Day 35	0%	3.220
	-	Day 35	10%	3.396
	-	Day 35	20%	3.405
	-	Day 35	30%	3.238

D vi) ANOVA table for feed conversion ratio at 47 days

Source	df	MS	F Value	Probability
Blocks	2	0.272	11.0504	0.0003
Strain	1	0.389	15.7933	0.0004
Starting date for bran feeding	1	0.002	0.0899	NS
Strain x Starting date	1	0.019	0.7857	NS
Bran levels	3	0.009	0.3843	NS
Strain x Bran levels	3	0.002	0.0645	NS
Starting date x Bran levels	3	0.008	0.3290	NS
Strain x starting date x Bran levels	3	0.014	0.5707	NS
Error	30	0.025		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean
Block	1	1.942a
	2	2.016b
	3	2.196b
Strain	Arbor acres	1.961a
	Cobb	2.141b
Starting date	Day 29	2.058
	Day 35	2.044
Bran level	0%	2.087
	10%	2.054
	20%	2.044
	30%	2.019

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean
Strain x Starting date	Arbor acres	Day 29	-	1.948
	Arbor acres	Day 35	-	1.974
	Cobb	Day 29	-	2.168
	Cobb	Day 35	-	2.114
Strain x Bran level	Arbor acres	-	0%	1.982
	Arbor acres	-	10%	1.962
	Arbor acres	-	20%	1.966
	Arbor acres	-	30%	1.934
	Cobb	-	0%	2.192
	Cobb	-	10%	2.145
	Cobb	-	20%	2.122
	Cobb	-	30%	2.104
Starting date x Bran level	-	Day 29	0%	2.087
	-	Day 29	10%	2.040
	-	Day 29	20%	2.089
	-	Day 29	30%	2.016
	-	Day 35	0%	2.087
	-	Day 35	10%	2.068
	-	Day 35	20%	2.000
	-	Day 35	30%	2.023

D vii) ANOVA table for Liveweight (kg) at 48days

Source	df	MS	F Value	Probability
Blocks	2	0.008	0.008	NS
Strain	1	3.393	188.9959	0.000
Starting date for bran feeding	1	0.000	0.0164	NS
Strain x Starting date	1	0.000	0.0170	NS
Bran levels	3	0.043	2.3957	0.0878
Strain x Bran levels	3	0.007	0.3781	NS
Starting date x Bran levels	3	0.005	0.3044	NS
Strain x starting date x Bran levels	3	0.007	0.3919	NS
Error	30	0.008		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (kg)
Block	1	1.838
	2	1.795
	3	1.830
Strain	Arbor acres	2.087a
	Cobb	1.555b
Starting date	Day 29	1.823
	Day 35	1.818
Bran level	0%	1.887a
	10%	1.813ab
	20%	1.840ab
	30%	1.743b

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (kg)
Strain x Starting date	Arbor acres	Day 29	-	2.087
	Arbor acres	Day 35	-	2.087
	Cobb	Day 29	-	1.560
	Cobb	Day 35	-	1.550
Strain x Bran level	Arbor acres	-	0%	2.187
	Arbor acres	-	10%	2.060
	Arbor acres	-	20%	2.093
	Arbor acres	-	30%	2.007
	Cobb	-	0%	1.587
	Cobb	-	10%	1.567
	Cobb	-	20%	1.587
	Cobb	-	30%	1.480
Starting date x Bran level	-	Day 29	0%	1.887
	-	Day 29	10%	1.847
	-	Day 29	20%	1.827
	-	Day 29	30%	1.733
	-	Day 35	0%	1.887
	-	Day 35	10%	1.780
	-	Day 35	20%	1.853
	-	Day 35	30%	1.753

D viii) ANOVA table for Carcass Weights at 48days

Source	df	MS	F Value	Probability
Blocks	2	0.010	1.3061	NS
Strain	1	2.225	291.5188	0.000
Starting date for bran feeding	1	0.000	0.000	NS
Strain x Starting date	1	0.000	0.0074	NS
Bran levels	3	0.022	2.9441	0.0489
Strain x Bran levels	3	0.008	1.0445	NS
Starting date x Bran levels	3	0.004	0.5196	NS
Strain x starting date x Bran levels	3	0.002	0.2174	NS
Error	30	0.008		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (kg)
Block	1	1.230
	2	1.180
	3	1.209
Strain	Arbor acres	1.422a
	Cobb	0.991b
Starting date	Day 29	1.206
	Day 35	1.206
Bran level	0%	1.251a
	10%	1.207ab
	20%	1.220a
	30%	1.147b

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (kg)
Strain x Starting date	Arbor acres	Day 29	-	1.420
	Arbor acres	Day 35	-	1.423
	Cobb	Day 29	-	0.992
	Cobb	Day 35	-	0.990
Strain x Bran level	Arbor acres	-	0%	1.502
	Arbor acres	-	10%	1.421
	Arbor acres	-	20%	1.410
	Arbor acres	-	30%	1.354
	Cobb	-	0%	1.000
	Cobb	-	10%	0.994
	Cobb	-	20%	1.030
	Cobb	-	30%	0.941
Starting date x Bran level	-	Day 29	0%	1.251
	-	Day 29	10%	1.233
	-	Day 29	20%	1.210
	-	Day 29	30%	1.131
	-	Day 35	0%	1.251
	-	Day 35	10%	1.182
	-	Day 35	20%	1.229
	-	Day 35	30%	1.164

D ix) ANOVA table for Dressing Out Percentage at 48days

Source	df	MS	F Value	Probability
Blocks	2	4.974	3.7217	0.0360
Strain	1	230.125	172.1724	0.0000
Starting date for bran feeding	1	0.585	0.4378	NS
Strain x Starting date	1	0.075	0.0563	NS
Bran levels	3	0.996	0.7450	NS
Strain x Bran levels	3	7.235	5.4131	0.0043
Starting date x Bran levels	3	1.385	1.0364	NS
Strain x starting date x Bran levels	3	1.067	0.7986	0.05
Error	30	1.337		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (%)
Block	1	66.525a
	2	65.419b
	3	65.850ab
Strain	Arbor acres	68.121a
	Cobb	63.742b
Starting date	Day 29	65.821
	Day 35	66.042
Bran level	0%	65.850
	10%	66.167
	20%	66.150
	30%	65.558

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (%)
Strain x Starting date	Arbor acres	Day 29	-	68.050
	Arbor acres	Day 35	-	68.192
	Cobb	Day 29	-	63.592
	Cobb	Day 35	-	63.892
Strain x Bran level	Arbor acres	-	0%	68.700a
	Arbor acres	-	10%	68.917a
	Arbor acres	-	20%	67.333a
	Arbor acres	-	30%	67.533a
	Cobb	-	0%	63.000b
	Cobb	-	10%	63.417b
	Cobb	-	20%	64.967b
	Cobb	-	30%	63.583b
Starting date x Bran level	-	Day 29	0%	65.850
	-	Day 29	10%	66.400
	-	Day 29	20%	66.050
	-	Day 29	30%	64.983
	-	Day 35	0%	65.850
	-	Day 35	10%	65.933
	-	Day 35	20%	66.250
	-	Day 35	30%	66.133

D x) ANOVA table for small intestine weights(g) at 48 days

Source	df	MS	F Value	Probability
Blocks	2	45.776	3.0074	0.0645
Strain	1	2195.107	144.2141	0.0000
Starting date for bran feeding	1	10.268	0.6746	NS
Strain x Starting date	1	19.001	1.2483	NS
Bran levels	3	109.670	7.2051	0.0009
Strain x Bran levels	3	19.192	1.2609	NS
Starting date x Bran levels	3	43.170	2.8362	0.0548
Strain x starting date x Bran levels	3	12.881	0.8462	0.05
Error	30	15.221		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (g)
Block	1	65.487a
	2	62.300b
	3	64.875a
Strain	Arbor acres	70.983a
	Cobb	57.458b
Starting date	Day 29	64.683
	Day 35	63.758
Bran level	0%	66.700a
	10%	64.333a
	20%	65.917a
	30%	59.933b

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (g)
Strain x Starting date	Arbor acres	Day 29	-	70.817
	Arbor acres	Day 35	-	71.150
	Cobb	Day 29	-	58.550
	Cobb	Day 35	-	56.367
Strain x Bran level	Arbor acres	-	0%	75.133
	Arbor acres	-	10%	71.267
	Arbor acres	-	20%	72.133
	Arbor acres	-	30%	65.400
	Cobb	-	0%	58.267
	Cobb	-	10%	57.400
	Cobb	-	20%	59.700
	Cobb	-	30%	54.467
Starting date x Bran level	-	Day 29	0%	66.700a
	-	Day 29	10%	67.267a
	-	Day 29	20%	64.267ab
	-	Day 29	30%	60.500b
	-	Day 35	0%	66.700a
	-	Day 35	10%	61.400b
	-	Day 35	20%	67.567a
	-	Day 35	30%	59.367b

D xi) ANOVA table for liver weights (g) at 48days

Source	df	MS	F Value	Probability
Blocks	2	3.090	0.2313	NS
Strain	1	1184.053	88.6194	0.0000
Starting date for bran feeding	1	6.453	0.4830	NS
Strain x Starting date	1	22.963	1.7187	NS
Bran levels	3	77.746	5.8188	0.0029
Strain x Bran levels	3	125.893	9.4224	0.0002
Starting date x Bran levels	3	2.373	0.1776	NS
Strain x starting date x Bran levels	3	58.030	4.3432	0.0118
Error	30	13.361		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (g)
Block	1	39.550
	2	39.400
	3	38.725
Strain	Arbor acres	44.192A
	Cobb	34.258b
Starting date	Day 29	38.858
	Day 35	39.592
Bran level	0%	43.000a
	10%	37.967b
	20%	38.433b
	30%	37.500b

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (g)
Strain x Starting date	Arbor acres	Day 29	-	43.133
	Arbor acres	Day 35	-	45.250
	Cobb	Day 29	-	34.583
	Cobb	Day 35	-	33.933
Strain x Bran level	Arbor acres	-	0%	51.133a
	Arbor acres	-	10%	39.200cd
	Arbor acres	-	20%	45.600ab
	Arbor acres	-	30%	40.833bc
	Cobb	-	0%	34.867cde
	Cobb	-	10%	36.733cde
	Cobb	-	20%	31.267e
	Cobb	-	30%	34.167de
Starting date x Bran level	-	Day 29	0%	43.000
	-	Day 29	10%	37.067
	-	Day 29	20%	37.867
	-	Day 29	30%	37.500
	-	Day 35	0%	43.000
	-	Day 35	10%	38.867
	-	Day 35	20%	39.000
	-	Day 35	30%	37.500

D xii) ANOVA table for Gizzard + Proventriculus (g) at 48 days

Source	df	MS	F Value	Probability
Blocks	2	108.640	4.0763	0.0272
Strain	1	617.767	23.1794	0.0000
Starting date for bran feeding	1	37.808	1.4186	NS
Strain x Starting date	1	2.167	0.0813	NS
Bran levels	3	14.770	0.5542	NS
Strain x Bran levels	3	6.208	0.2329	NS
Starting date x Bran levels	3	24.448	0.9173	NS
Strain x starting date x Bran levels	3	3.243	0.1217	0.05
Error	30	26.652		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (g)
Block	1	65.437a
	2	60.237b
	3	63.138ab
Strain	Arbor acres	66.525
	Cobb	59.350
Starting date	Day 29	63.825
	Day 35	62.050
Bran level	0%	62.933
	10%	61.600
	20%	64.317
	30%	62.900

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (g)
Strain x Starting date	Arbor acres	Day 29	-	67.200
	Arbor acres	Day 35	-	65.850
	Cobb	Day 29	-	60.450
	Cobb	Day 35	-	58.250
Strain x Bran level	Arbor acres	-	0%	66.333
	Arbor acres	-	10%	65.700
	Arbor acres	-	20%	66.967
	Arbor acres	-	30%	67.100
	Cobb	-	0%	59.533
	Cobb	-	10%	57.500
	Cobb	-	20%	61.667
	Cobb	-	30%	58.700
Starting date x Bran level	-	Day 29	0%	62.933
	-	Day 29	10%	61.767
	-	Day 29	20%	67.333
	-	Day 29	30%	63.267
	-	Day 35	0%	62.933
	-	Day 35	10%	61.433
	-	Day 35	20%	61.300
	-	Day 35	30%	62.533

D xiii) ANOVA table for Abdominal Fat weights (g) at 48 days

Source	df	MS	F Value	Probability
Blocks	2	33.499	0.4880	NS
Strain	1	713.792	10.3972	0.0030
Starting date for bran feeding	1	635.835	9.2617	0.0048
Strain x Starting date	1	34.172	0.4978	NS
Bran levels	3	31.602	0.4603	NS
Strain x Bran levels	3	66.954	0.9753	NS
Starting date x Bran levels	3	11.472	0.1671	NS
Strain x starting date x Bran levels	3	30.807	0.4487	0.05
Error	30	68.652		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (g)
Block	1	34.131
	2	36.988
	3	35.963
Strain	Arbor acres	39.550a
	Cobb	31.838b
Starting date	Day 29	39.333a
	Day 35	32.054b
Bran level	0%	33.667
	10%	37.267
	20%	35.142
	30%	36.700

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (g)
Strain x Starting date	Arbor acres	Day 29	-	44.033
	Arbor acres	Day 35	-	35.067
	Cobb	Day 29	-	34.633
	Cobb	Day 35	-	29.042
Strain x Bran level	Arbor acres	-	0%	39.533
	Arbor acres	-	10%	40.100
	Arbor acres	-	20%	40.867
	Arbor acres	-	30%	37.700
	Cobb	-	0%	27.800
	Cobb	-	10%	34.433
	Cobb	-	20%	29.417
	Cobb	-	30%	35.700
Starting date x Bran level	-	Day 29	0%	33.667
	-	Day 29	10%	40.500
	-	Day 29	20%	38.633
	-	Day 29	30%	44.533
	-	Day 35	0%	33.667
	-	Day 35	10%	34.033
	-	Day 35	20%	31.650
	-	Day 35	30%	28.867

D xiv) ANOVA table for colon weights (g) at 48 days

Source	df	MS	F Value	Probability
Blocks	2	0.783	2.2269	NS
Strain	1	1.687	4.8024	0.0363
Starting date for bran feeding	1	0.241	0.6854	NS
Strain x Starting date	1	0.068	0.1921	NS
Bran levels	3	0.770	2.1905	NS
Strain x Bran levels	3	0.256	0.7293	NS
Starting date x Bran levels	3	0.614	1.7478	NS
Strain x starting date x Bran levels	3	0.156	0.4451	0.05
Error	30	0.351		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (g)
Block	1	5.362
	2	4.925
	3	5.200
Strain	Arbor acres	5.350a
	Cobb	4.975b
Starting date	Day 29	5.233
	Day 35	5.092
Bran level	0%	5.533
	10%	5.050
	20%	5.100
	30%	4.967

b) *Two factor means*

Type of Interaction	Strain	Starting date	Bran Level	Mean (g)
Strain x Starting date	Arbor acres	Day 29	-	5.383
	Arbor acres	Day 35	-	5.317
	Cobb	Day 29	-	5.083
	Cobb	Day 35	-	4.867
Strain x Bran level	Arbor acres	-	0%	5.533
	Arbor acres	-	10%	5.200
	Arbor acres	-	20%	5.367
	Arbor acres	-	30%	5.300
	Cobb	-	0%	5.533
	Cobb	-	10%	4.900
	Cobb	-	20%	4.833
	Cobb	-	30%	4.633
Starting date x Bran level	-	Day 29	0%	5.533
	-	Day 29	10%	5.200
	-	Day 29	20%	4.900
	-	Day 29	30%	5.300
	-	Day 35	0%	5.533
	-	Day 35	10%	4.900
	-	Day 35	20%	5.300
	-	Day 35	30%	4.633

D xv) ANOVA table for caecae weights (g) at 48 days

Source	df	MS	F Value	Probability
Blocks	2	0.070	0.1691	NS
Strain	1	11.603	28.0274	0.000
Starting date for bran feeding	1	0.120	0.2899	NS
Strain x Starting date	1	3.000	7.2464	0.011
Bran levels	3	1.428	3.4487	0.028
Strain x Bran levels	3	0.686	1.6559	NS
Starting date x Bran levels	3	1.149	2.7751	0.058
Strain x starting date x Bran levels	3	0.620	1.4976	0.05
Error	30	0.414		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (g)
Block	1	11.925
	2	11.800
	3	11.900
Strain	Arbor acres	12.367a
	Cobb	11.383b
Starting date	Day 29	11.825
	Day 35	11.925
Bran level	0%	11.533b
	10%	11.967ab
	20%	12.317a
	30%	11.683b

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (g)
Strain x Starting date	Arbor acres	Day 29	-	12.067ab
	Arbor acres	Day 35	-	12.667a
	Cobb	Day 29	-	11.583bc
	Cobb	Day 35	-	11.183c
Strain x Bran level	Arbor acres	-	0%	12.000
	Arbor acres	-	10%	12.167
	Arbor acres	-	20%	12.833
	Arbor acres	-	30%	12.467
	Cobb	-	0%	11.067
	Cobb	-	10%	11.767
	Cobb	-	20%	11.800
	Cobb	-	30%	10.900
Starting date x Bran level	-	Day 29	0%	11.533
	-	Day 29	10%	12.000
	-	Day 29	20%	12.567
	-	Day 29	30%	11.200
	-	Day 35	0%	11.533
	-	Day 35	10%	11.933
	-	Day 35	20%	12.067
	-	Day 35	30%	12.167

D xvi) ANOVA table for Finisher Feed Costs (K) at 43 days

Source	df	MS	F Value	Probability
Blocks	2	20442.563	1.8250	NS
Strain	1	808861.688	72.2110	0.0000
Starting date for bran feeding	1	2898.521	0.2588	NS
Strain x Starting date	1	4820.021	0.4303	NS
Bran levels	3	179245.688	16.0021	0.0000
Strain x Bran levels	3	18831.688	1.6812	NS
Starting date x Bran levels	3	12012.854	1.0724	NS
Strain x starting date x Bran levels	3	33708.132	3.0093	0.0456
Error	30	11201.363		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (K)
Block	1	1160.000
	2	1177.625
	3	1228.813
Strain	Arbor acres	1318.625a
	Cobb	1059.000b
Starting date	Day 29	1181.042
	Day 35	1196.583
Bran level	0%	1314.833a
	10%	1260.833a
	20%	1135.250b
	30%	1044.333b

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (K)
Strain x Starting date	Arbor acres	Day 29	-	1300.833
	Arbor acres	Day 35	-	1336.417
	Cobb	Day 29	-	1061.250
	Cobb	Day 35	-	1056.750
Strain x Bran level	Arbor acres	-	0%	1459.000
	Arbor acres	-	10%	1402.000
	Arbor acres	-	20%	1297.167
	Arbor acres	-	30%	1116.333
	Cobb	-	0%	1170.667
	Cobb	-	10%	1119.667
	Cobb	-	20%	973.333
	Cobb	-	30%	972.333
Starting date x Bran level	-	Day 29	0%	1314.833
	-	Day 29	10%	1229.833
	-	Day 29	20%	1169.000
	-	Day 29	30%	1010.500
	-	Day 35	0%	1314.833
	-	Day 35	10%	1291.833
	-	Day 35	20%	1101.500
	-	Day 35	30%	1078.167

D xvii) ANOVA table for Total Feed Costs (K) at 43 days

Source	df	MS	F Value	Probability
Blocks	2	15858.250	1.1784	NS
Strain	1	1907620.021	141.7574	0.0000
Starting date for bran feeding	1	26273.521	1.9524	NS
Strain x Starting date	1	325.521	0.0242	NS
Bran levels	3	186475.132	13.8572	0.0000
Strain x Bran levels	3	33983.576	2.5254	0.0764
Starting date x Bran levels	3	16805.187	1.2488	NS
Strain x starting date x Bran levels	3	52794.299	3.9232	0.0178
Error	30	13456.939		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (K)
Block	*1*	*1990.313*
	2	*1999.063*
	3	2048.688
Strain	Arbor acres	2212.042a
	Cobb	1813.333b
Starting date	Day 29	1989.292
	Day 35	2036.083
Bran level	0%	2149.667a
	10%	2065.417ab
	20%	1977.333bc
	30%	1858.333c

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (K)
Strain x Starting date	Arbor acres	Day 29	-	2191.250
	Arbor acres	Day 35	-	2232.833
	Cobb	Day 29	-	1787.333
	Cobb	Day 35	-	1839.333
Strain x Bran level	Arbor acres	-	0%	2340.667
	Arbor acres	-	10%	2302.833
	Arbor acres	-	20%	2219.000
	Arbor acres	-	30%	1985.667
	Cobb	-	0%	1958.667
	Cobb	-	10%	1828.000
	Cobb	-	20%	1735.667
	Cobb	-	30%	1731.000
Starting date x Bran level	-	Day 29	0%	2149.667
	-	Day 29	10%	1995.667
	-	Day 29	20%	1990.333
	-	Day 29	30%	1821.500
	-	Day 35	0%	2149.667
	-	Day 35	10%	2135.167
	-	Day 35	20%	1964.333
	-	Day 35	30%	1895.167

D xviii) ANOVA table forFinisher Feed Costs (K) at 47 days

Source	df	MS	F Value	Probability
Blocks	2	29036.583	1.8360	NS
Strain	1	146081.021	72.4670	0.0000
Starting date for bran feeding	1	6603.521	0.4175	NS
Strain x Starting date	1	18762.521	1.1864	NS
Bran levels	3	346090.188	21.8834	0.0000
Strain x Bran levels	3	19203.132	1.2142	NS
Starting date x Bran levels	3	7895.188	0.4992	NS
Strain x starting date x Bran levels	3	39976.188	2.577	0.0762
Error	30	15815.206		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (K)
Block	1	1472.063
	2	1497.438
	3	1555.188
Strain	Arbor acres	1662.750a
	Cobb	1353.708b
Starting date	Day 29	1496.500
	Day 35	1519.958
Bran level	0%	1707.500a
	10%	1569.750ab
	20%	1445.000bc
	30%	1310.667c

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (K)
Strain x Starting date	Arbor acres	Day 29	-	1631.250
	Arbor acres	Day 35	-	1694.250
	Cobb	Day 29	-	1361.750
	Cobb	Day 35	-	1345.667
Strain x Bran level	Arbor acres	-	0%	1866.667
	Arbor acres	-	10%	1748.000
	Arbor acres	-	20%	1629.000
	Arbor acres	-	30%	1407.333
	Cobb	-	0%	1548.333
	Cobb	-	10%	1391.500
	Cobb	-	20%	1261.000
	Cobb	-	30%	1214.000
Starting date x Bran level	-	Day 29	0%	1707.500
	-	Day 29	10%	1546.000
	-	Day 29	20%	1462.500
	-	Day 29	30%	1270.000
	-	Day 35	0%	1707.500
	-	Day 35	10%	1593.500
	-	Day 35	20%	1427.500
	-	Day 35	30%	1351.333

D xix) ANOVA table forTotal Feed Costs (K) at 47 days

Source	df	MS	F Value	Probability
Blocks	2	20626.083	1.0705	NS
Strain	1	2611467.000	135.5385	0.0000
Starting date for bran feeding	1	33496.333	1.7385	NS
Strain x Starting date	1	10620.750	0.5512	NS
Bran levels	3	315074.250	16.3528	0.0000
Strain x Bran levels	3	25263.278	1.3112	NS
Starting date x Bran levels	3	6224.056	0.3230	NS
Strain x starting date x Bran levels	3	52446.139	2.7220	0.0618
Error	30	19267.350		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (K)
Block	1	2316.000
	2	2332.000
	3	2384.625
Strain	Arbor acres	2577.458a
	Cobb	2110.958b
Starting date	Day 29	2317.792
	Day 35	2370.625
Bran level	0%	2531.667a
	10%	2398.917ab
	20%	2298.333bc
	30%	2147.917c

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (K)
Strain x Starting date	Arbor acres	Day 29	-	2536.167
	Arbor acres	Day 35	-	2618.750
	Cobb	Day 29	-	2099.417
	Cobb	Day 35	-	2122.500
Strain x Bran level	Arbor acres	-	0%	2763.000
	Arbor acres	-	10%	2662.833
	Arbor acres	-	20%	2567.000
	Arbor acres	-	30%	2317.000
	Cobb	-	0%	2300.333
	Cobb	-	10%	2135.000
	Cobb	-	20%	2029.667
	Cobb	-	30%	1978.833
Starting date x Bran level	-	Day 29	0%	2531.667
	-	Day 29	10%	2354.500
	-	Day 29	20%	2283.500
	-	Day 29	30%	2101.500
	-	Day 35	0%	2531.667
	-	Day 35	10%	2443.333
	-	Day 35	20%	2313.167
	-	Day 35	30%	2194.333

D xx) ANOVA table for Gross Margin Returns (%) at 47 days

Source	df	MS	F Value	Probability
Blocks	2	24.084	1.0782	NS
Strain	1	80.523	3.6050	0.0673
Starting date for bran feeding	1	29.657	1.3278	NS
Strain x Starting date	1	8.492	0.3802	NS
Bran levels	3	312.371	13.9848	0.0000
Strain x Bran levels	3	19.968	0.8940	NS
Starting date x Bran levels	3	11.065	0.4954	NS
Strain x starting date x Bran levels	3	56.922	2.5484	0.0745
Error	30	22.337		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (%)
Block	1	46.963
	2	46.694
	3	44.716
Strain	Arbor acres	44.829b
	Cobb	47.420a
Starting date	Day 29	46.910
	Day 35	45.338
Bran level	0%	40.165c
	10%	44.439bc
	20%	47.653ab
	30%	52.240a

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (%)
Strain x Starting date	Arbor acres	Day 29	-	46.036
	Arbor acres	Day 35	-	43.622
	Cobb	Day 29	-	47.785
	Cobb	Day 35	-	47.054
Strain x Bran level	Arbor acres	-	0%	39.653
	Arbor acres	-	10%	42.282
	Arbor acres	-	20%	45.050
	Arbor acres	-	30%	52.332
	Cobb	-	0%	40.677
	Cobb	-	10%	46.597
	Cobb	-	20%	50.257
	Cobb	-	30%	52.148
Starting date x Bran level	-	Day 29	0%	40.165
	-	Day 29	10%	46.003
	-	Day 29	20%	47.565
	-	Day 29	30%	53.908
	-	Day 35	0%	40.165
	-	Day 35	10%	42.875
	-	Day 35	20%	47.742
	-	Day 35	30%	50.572

D xxi) ANOVA table for Gross Margin Returns at 47 days at 2% Mortality rate for Arbor acres

Source	df	MS	F Value	Probability
Blocks	2	22.537	0.9469	NS
Strain	1	544.659	22.8842	0.0000
Starting date for bran feeding	1	38.646	1.6237	NS
Strain x Starting date	1	13.579	0.5705	NS
Bran levels	3	349.434	14.6817	0.0000
Strain x Bran levels	3	23.748	0.9978	NS
Starting date x Bran levels	3	11.197	0.4704	NS
Strain x starting date x Bran levels	3	62.079	2.6083	0.0698
Error	30	23.801		
TOTAL	47			

MEANS FOR FACTORS AND INTERACTIONS

Means within the same factor and followed by the same letter are not significantly different, at the significance level indicated in the ANOVA table.

a) Single Factor Means

Factor	Level	Mean (%)
Block	1	51.444
	2	51.503
	3	49.418
Strain	Arbor acres	54.157a
	Cobb	47.420b
Starting date	Day 29	51.685
	Day 35	49.891
Bran level	0%	44.515c
	10%	48.988bc
	20%	52.357ab
	30%	57.292a

b) Two factor means

Type of Interaction	Strain	Starting date	Bran Level	Mean (%)
Strain x Starting date	Arbor acres	Day 29	-	55.586
	Arbor acres	Day 35	-	52.728
	Cobb	Day 29	-	47.785
	Cobb	Day 35	-	47.054
Strain x Bran level	Arbor acres	-	0%	48.353
	Arbor acres	-	10%	51.380
	Arbor acres	-	20%	54.457
	Arbor acres	-	30%	62.437
	Cobb	-	0%	40.677
	Cobb	-	10%	46.597
	Cobb	-	20%	50.257
	Cobb	-	30%	52.148
Starting date x Bran level	-	Day 29	0%	44.515
	-	Day 29	10%	50.527
	-	Day 29	20%	52.502
	-	Day 29	30%	59.198
	-	Day 35	0%	44.515
	-	Day 35	10%	47.450
	-	Day 35	20%	52.212
	-	Day 35	30%	55.387

APPENDIX E: LINEAR CORRELATION MATRICES

APPENDIX E i) LINEAR CORRELATION COEFFICIENTS FOR BRAN LEVEL, LIVEWEIGHT, FEED CONSUMPTION, FCR AND CARCASS CHARACTERISICS FOR ARBOR ACRES FED BRAN FROM DAY 29

--	*L.wt 43	F.Cons 43	FCR 43	L.wt 47	F.Cons 47	FCR 47	L.wt 48	D.wt	D.out	SI	Liv	G+P	AF	Cae	Col
Bran:	-0.01	-0.55	-.041	-0.31	-0.71	-0.87	-0.86	-0.99	-0.87	-0.99	-0.49	0.66	0.99	0.13	-0.16
L.wt: 43	1.00	-0.24	-0.73	0.28	-0.20	-0.46	-0.13	0.33	-0.17	0.05	0.37	-0.47	-0.11	0.99	-0.97
F.Cons 43:	1.00	0.84	0.83	0.98	0.73	0.06	0.41	0.89	0.59	-0.45	-0.72	-0.55	-0.37	0.16	
FCR 43:		1.00	0.42	0.80	0.79	0.25	0.30	0.73	0.40	-0.50	-0.25	-0.35	-0.82	0.66	
L. wt 47:			1.00	0.78	0.29	0.15	0.16	0.64	0.37	-0.48	-0.87	-0.36	0.17	-0.41	
F. Cons 47:				1.00	0.83	0.26	0.59	0.96	0.75	0.26	-0.78	-0.71	-0.34	0.16	
FCR 47:					1.00	0.61	0.81	0.92	0.85	0.12	-0.46	-0.82	-0.59	0.55	
L. wt 48:						1.00	0.93	0.51	0.84	0.86	-0.33	-0.85	-0.04	0.12	
D. wt:							1.00	0.79	0.98	0.62	-0.57	-0.98	-0.09	0.16	
D. out:								1.00	0.89	-0.03	-0.77	-0.87	-0.32	-0.20	
SI:									1.00	0.46	-0.72	-0.99	-0.09	0.10	
Liver:										1.00	0.02	-0.50	0.36	-0.11	
G+P											1.00	0.72	-0.33	0.47	
AF												1.00	0.03	-0.05	
Caeca													1.00	-0.96	
Colon														1.00	

Values greater than or equal to .95 are significant at $p \leq 0.05$ (Little and Hills, 1978)

Values greater than or equal to .99 are significant at $p \leq 0.01$ (Little and Hills, 1978)

*L. wt	Liveweight	D. wt	Dressed weight	A.F.	Abdominal Fat
F. Cons	Food Consumption	D. out	Dressing out %		
FCR	Feed Conversion Ratio	S.I	Small Intestine		
43, 47, 48	Days of age of birds	G+P	Gizzard and Proventriculus		

APPENDIX E ii) LINEAR CORRELATION COEFFICIENTS FOR BRAN LEVEL, LIVEWEIGHT, FEED CONSUMPTION, FCR AND CARCASS CHARACTERISICS FOR ARBOR ACRES FED BRAN FROM DAY 35

--	*L.wt 43	F.Cons 43	FCR 43	L.wt 47	F.Cons 47	FCR 47	L.wt 48	D.wt	D.out	SI	Liv	G+P	A.F.	Cae	Col
Bran:	-0.07	-0.41	0.68	-0.57	-0.47	0.46	-0.79	-0.92	-0.41	-0.67	-0.58	-0.22	-0.92	-0.42	0.96
L.wt 43	1.00	0.52	0.10	0.67	0.73	0.64	0.61	0.35	-0.87	0.79	0.80	-0.87	0.34	0.93	0.21
F.Cons 43:	1.00	0.76	0.98	0.99	0.36	0.54	0.41	-0.54	0.79	0.58	-0.76	0.73	0.77	-0.21	
FCR 43:		1.00	0.79	0.76	-0.13	0.25	0.30	0.06	0.42	0.12	-0.25	0.76	0.25	-0.53	
L. wt 47:			1.00	0.98	0.18	0.65	0.56	-0.41	0.86	0.65	-0.64	0.84	0.79	-0.38	
F. Cons 47:				1.00	0.30	0.60	0.47	-0.51	0.83	0.63	-0.73	0.77	0.80	-0.26	
FCR 47:					1.00	0.23	-0.50	-0.94	0.05	0.05	-0.86	-0.37	0.31	0.84	
L. wt 48:						1.00	0.96	-0.12	0.94	0.96	-0.21	0.80	0.84	0.60	
D. wt:							1.00	0.17	0.83	0.83	0.06	0.85	0.66	0.80	
D. out:								1.00	0.39	0.39	0.95	0.09	-0.63	-0.65	
S.I.:									1.00	0.95	0.51	0.83	0.95	-0.44	
Liver:										1.00	0.43	0.66	0.94	-0.34	
G+P:											1.00	-0.15	-0.69	-0.45	
AF												1.00	0.63	-0.81	
Caeca:													1.00	-0.15	
Colon:														1.00	

Values greater than or equal to .95 are significant at $p \leq 0.05$ (Little and Hills, 1978)

Values greater than or equal to .99 are significant at $p \leq 0.05$ (Little and Hills, 1978)

*L. wt	Liveweight	D. wt	Dressed weight	A.F.	Abdominal Fat
F. Cons	Food Consumption	D. out	Dressing out %		
FCR	Feed Conversion Ratio	S.I	Small Intestine		
43, 47, 48	Days of age of birds	G+P	Gizzard and Proventriculus		

APPENDIX E iii) LINEAR CORRELATION COEFFICIENTS FOR BRAN LEVEL, LIVEWEIGHT, FEED CONSUMPTION, FCR AND CARCASS CHARACTERISICS FOR COBB FED BRAN FROM DAY 29

--	*L.wt 43	F.Cons 43	FCR 43	L.wt 47	F.Cons 47	FCR 47	L.wt 48	D.wt	D.out	SI	Liv	G+P	A.F.	Cae	Col
Bran:	0.47	0.15	-0.40	-0.04	-0.01	-0.03	-0.76	-0.65	0.37	0.57	-0.72	0.18	0.67	-0.88	-0.09
L.wt: 43	1.00	0.30	-0.27	0.86	0.19	0.02	0.20	0.32	0.77	0.45	0.26	0.28	0.53	-0.78	0.69
F. Cons 43:	1.00	0.84	0.54	0.97	0.92	0.56	0.66	0.80	0.50	0.21	0.93	-0.63	-0.26	0.86	
FCR 43:		1.00	0.05	0.87	0.92	0.44	0.47	0.38	0.24	0.05	0.78	-0.93	0.17	0.47	
L. wt 47:			1.00	0.36	0.17	0.67	0.76	0.74	0.84	0.67	0.35	0.11	-0.41	0.90	
F. Cons 47:				1.00	0.98	0.36	0.47	0.78	0.29	-0.02	0.98	-0.64	-0.32	0.73	
FCR 47:					1.00	0.25	0.35	0.66	0.14	-0.15	0.96	-0.71	-0.23	0.59	
L. wt 48:						1.00	0.99	0.28	0.96	0.92	0.21	-0.51	0.35	0.70	
D. wt:							1.00	0.43	0.97	0.87	0.34	-0.48	0.20	0.81	
D. out:								1.00	0.40	0.07	0.83	-0.05	-0.76	0.88	
S.I.:									1.00	0.94	0.17	-0.26	0.14	0.77	
Liver:										1.00	-0.16	-0.03	0.39	0.51	
G+P:											1.00	-0.50	-0.48	0.71	
A.F.:												1.00	-0.52	-0.26	
Caeca:													1.00	0.40	
Colon:														1.00	

Values greater than or equal to .95 are significant at $p \leq 0.05$ (Little and Hills, 1978)

Values greater than or equal to .99 are significant at $p \leq 0.05$ (Little and Hills, 1978)

*L. wt	Liveweight	D. wt	Dressed weight	AF	Abdominal Fat
F. Cons	Food Consumption	D. out	Dressing out %		
FCR	Feed Conversion Ratio	S.I	Small Intestine		
43, 47, 48	Days of age of birds	G+P	Gizzard and Proventriculus		

APPENDIX E iv) LINEAR CORRELATION COEFFICIENTS FOR BRAN LEVEL, LIVEWEIGHT, FEED CONSUMPTION, FCR AND CARCASS CHARACTERISICS FOR COBB FED BRAN FROM DAY 35

--	*L.wt 43	F.Cons 43	FCR 43	L.wt 47	F.Cons 47	FCR 47	L.wt 48	D.wt	D.out	SI	Liv	G+P	A.F.	Cae	Col
Bran:	0.16	-0.84	-0.79	0.24	-0.91	-0.85	-0.39	-0.02	0.57	-0.20	0.08	-0.13	0.45	-0.86	-0.29
L.wt 43	1.00	-0.21	-0.62	0.92	0.11	-0.66	0.85	0.96	0.75	0.93	-0.01	0.48	-0.81	0.33	0.93
F. Cons. 43:		1.00	0.89	-0.06	0.92	0.74	0.24	0.05	-0.26	0.12	-0.61	-0.39	-0.37	0.59	0.50
FCR 43:			1.00	-0.49	0.71	0.93	-0.16	-0.40	-0.60	-0.31	-0.42	-0.46	0.05	0.38	0.80
L. wt 47:				1.00	0.14	-0.68	0.72	0.95	0.91	0.85	-0.38	0.10	-0.73	0.16	-0.73
F Cons. 47:					1.00	0.63	0.58	0.33	-0.19	0.45	-0.41	-0.03	-0.67	0.85	0.15
FCR 47:						1.00	-0.16	-0.51	-0.84	-0.35	-0.04	-0.14	0.09	0.48	0.71
L.wt 48:							1.00	0.90	0.38	0.98	0.02	0.55	-0.99	0.78	0.72
D. wt:								1.00	0.74	0.97	0.22	0.33	-0.90	0.45	-0.79
D. out:									1.00	0.56	-0.45	-0.15	-0.39	-0.25	-0.58
S.I.:										1.00	-0.09	0.48	-0.96	0.63	-0.80
Liver:											1.00	0.83	0.17	-0.08	-0.36
G+P:												1.00	-0.42	0.50	-0.72
A.F.:													1.00	0.79	0.62
Caeca:														1.00	-0.24
Colon:															1.00

Values greater than or equal to .95 are significant at $p \leq 0.05$ (Little and Hills, 1978)

Values greater than or equal to .99 are significant at $p \leq 0.05$ (Little and Hills, 1978)

*L. wt	Liveweight	D. wt	Dressed weight	AF	Abdominal Fat
F. Cons	Food Consumption	D. out	Dressing out %		
FCR	Feed Conversion Ratio	S.I	Small Intestine		
43, 47, 48	Days of age of birds	G+P	Gizzard and Proventriculus		

APPENDIX F: GROSS MARGIN BUDGETS

APPENDIX F i): GROSS MARGIN RETURNS FOR ARBOR ACRES AT 47 DAYS FOR 6.2% MORTALITY RATE

Block 1:

&TREATMENT	A/0/29	A/10/29	A/20/29	A/30/29	A/0/35	A/10/35	A/20/35	A/30/35
REVENUE (K)	7500	7500	7500	7500	7500	7500	7500	7500
VARIABLE COSTS (K)								
FEED	2836	2530	2361	2259	2836	2687	2593	2378
*OTHER	2608	2608	2608	2608	2608	2608	2608	2608
TOTAL	5444	5138	4969	4867	5444	5295	5201	4986
# GROSS MARGIN (K)	2056	2362	2531	2636	2056	2205	2299	2514
@GROSS MARGIN (%)	37.77	45.97	50.94	54.19	37.77	41.64	44.20	50.42

& A = Arbor acres; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird:- Mortality at 6.2 %, costing K 465 per bird.
- Chicks at K 1,350
- Labour at K 333
- Veterinary costs at K 145
- Transport at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 7,500 per live Arbor acres bird.

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

Block 2:

&TREATMENT	A/0/29	A/10/29	A/20/29	A/30/29	A/0/35	A/10/35	A/20/35	A/30/35
REVENUE (K)	7500	7500	7500	7500	7500	7500	7500	7500
VARIABLE COSTS (K)								
FEED	2723	2652	2510	2303	2723	2623	2840	2392
*OTHER	2608	2608	2608	2608	2608	2608	2608	2608
TOTAL	5331	5260	5118	4911	5331	5231	5448	5000
# GROSS MARGIN (K)	2169	2240	2382	2589	2169	2259	2052	2500
@GROSS MARGIN (%)	40.69	42.59	46.54	52.72	40.69	43.10	37.67	50.00

& A = Arbor acres; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird:- Mortality at 6.2 %, costing K 465 per bird.
- Chicks at K 1,350
- Labour at K 333
- Veterinary costs at K 145
- Transport at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 7,500 per live Arbor acres bird.

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

Block 3:

&TREATMENT	A/0/29	A/10/29	A/20/29	A/30/29	A/0/35	A/10/35	A/20/35	A/30/35
REVENUE (K)	7500	7500	7500	7500	7500	7500	7500	7500
VARIABLE COSTS (K)								
FEED	2730	2817	2461	2252	2730	2668	2637	2317
*OTHER	2608	2608	2608	2608	2608	2608	2608	2608
TOTAL	5338	5425	5069	4860	5338	5276	5245	4925
# GROSS MARGIN (K)	2162	2075	2431	2640	2162	2224	2255	2575
@GROSS MARGIN (%)	40.50	38.24	47.96	54.32	40.50	42.15	42.99	52.28

& A = Arbor acres; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird:- Mortality at 6.2 %, costing K 465 per bird.
- Chicks at K 1,350
- Labour at K 333
- Veterinary costs at K 145
- Transport at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 7,500 per live Arbor acres bird.

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

APPENDIX Fii): GROSS MARGIN RETURNS FOR COBB 500 AT 47 DAYS FOR 1.8 % MORTALITY RATE

Block 1:

&TREATMENT	C/0/29	C/10/29	C/20/29	C/30/29	C/0/35	C/10/35	C/20/35	C/30/35
REVENUE (K)	6000	6000	6000	6000	6000	6000	6000	6000
VARIABLE COSTS (K)								
FEED	2117	2025	2191	1886	2117	2015	2149	2075
*OTHER	1969	1969	1969	1969	1969	1969	1969	1969
TOTAL	4086	3994	4160	3855	4086	3984	4118	4044
# GROSS MARGIN (K)	1914	2006	1840	2145	1914	2016	1882	1956
@GROSS MARGIN (%)	46.84	50.23	44.23	55.64	46.84	50.60	45.70	48.37

& C = Cobb 500; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird: - Mortality at 1.8%, costing K 126 per bird.
- Chicks at K 1,050
- Labour at K 333
- Veterinary costs at K 145
- Transport costs at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 6,000 per live Cobb bird

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

Block 2:

[&]TREATMENT	C/0/29	C/10/29	C/20/29	C/30/29	C/0/35	C/10/35	C/20/35	C/30/35
REVENUE (K)	6000	6000	6000	6000	6000	6000	6000	6000
VARIABLE COSTS (K)								
FEED	2432	1884	2078	1763	2432	2096	1799	2062
*OTHER	1969	1969	1969	1969	1969	1969	1969	1969
TOTAL	4401	3853	4047	3732	4401	4065	3768	4031
[#] GROSS MARGIN (K)	1599	2147	1953	2268	1599	1935	2232	1969
[@]GROSS MARGIN (%)	36.33	55.72	48.26	60.77	36.33	47.60	59.24	48.85

[&] C = Cobb 500; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird: - Mortality at 1.8%, costing K 126 per bird.
- Chicks at K 1,050
- Labour at K 333
- Veterinary costs at K 145
- Transport costs at K 222
- Litter at K 93

[#]Gross Margin = Revenue - Variable Costs, where Revenue is K 6,000 per live Cobb bird

[@]Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

Block 3:

&TREATMENT	C/0/29	C/10/29	C/20/29	C/30/29	C/0/35	C/10/35	C/20/35	C/30/35
REVENUE (K)	6000	6000	6000	6000	6000	6000	6000	6000
VARIABLE COSTS (K)								
FEED	2352	2219	2100	2146	2352	2571	1861	1941
*OTHER	1969	1969	1969	1969	1969	1969	1969	1969
TOTAL	4321	4188	4069	4115	4321	4540	3830	3910
# GROSS MARGIN (K)	1679	1812	1931	1885	1679	1460	2170	2090
@GROSS MARGIN (%)	38.86	43.27	47.46	45.81	38.86	32.16	56.65	53.45

& C = Cobb 500; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird: - Mortality at 1.8%, costing K 126 per bird.
- Chicks at K 1,050
- Labour at K 333
- Veterinary costs at K 145
- Transport costs at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 6,000 per live Cobb bird

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

APPENDIX Fiii): GROSS MARGIN RETURNS FOR ARBOR ACRES AT 47 DAYS FOR 2% MORTALITY RATE

Block 1:

&TREATMENT	A/0/29	A/10/29	A/20/29	A/30/29	A/0/35	A/10/35	A/20/35	A/30/35
REVENUE (K)	7500	7500	7500	7500	7500	7500	7500	7500
VARIABLE COSTS (K)								
FEED	2836	2530	2361	2259	2836	2687	2593	2378
*OTHER	2293	2293	2293	2293	2293	2293	2293	2293
TOTAL	5129	4823	4654	4552	5129	4980	4888	4672
# GROSS MARGIN (K)	2371	2677	2846	2948	2371	2520	2612	2828
@GROSS MARGIN (%)	46.23	55.50	61.15	64.76	46.23	50.60	53.44	56.74

& A = Arbor acres; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird:- Mortality at 6.2 %, costing K 465 per bird.
- Chicks at K 1,350
- Labour at K 333
- Veterinary costs at K 145
- Transport at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 7,500 per live Arbor acres bird.

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

Block 2:

&TREATMENT	A/0/29	A/10/29	A/20/29	A/30/29	A/0/35	A/10/35	A/20/35	A/30/35
REVENUE (K)	7500	7500	7500	7500	7500	7500	7500	7500
VARIABLE COSTS (K)								
FEED	2723	2652	2510	2303	2723	2623	2840	2392
*OTHER	2293	2293	2293	2293	2293	2293	2293	2293
TOTAL	5016	4945	4803	4596	5016	4916	5133	4685
# GROSS MARGIN (K)	2484	2555	2697	2904	2484	2584	2367	2915
@GROSS MARGIN (%)	49.52	51.67	56.15	63.19	49.52	52.56	46.11	62.22

& A = Arbor acres; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird:- Mortality at 6.2 %, costing K 465 per bird.
- Chicks at K 1,350
- Labour at K 333
- Veterinary costs at K 145
- Transport at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 7,500 per live Arbor acres bird.

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

Block 3:

&TREATMENT	A/0/29	A/10/29	A/20/29	A/30/29	A/0/35	A/10/35	A/20/35	A/30/35
REVENUE (K)	7500	7500	7500	7500	7500	7500	7500	7500
VARIABLE COSTS (K)								
FEED	2730	2817	2461	2252	2730	2668	2637	2317
*OTHER	2293	2293	2293	2293	2293	2293	2293	2293
TOTAL	5023	5110	4754	4545	5023	4961	4930	4610
# GROSS MARGIN (K)	2477	2390	2746	2955	2477	2539	2570	2890
@GROSS MARGIN (%)	49.31	46.77	57.76	65.02	49.31	51.18	52.13	62.69

& A = Arbor acres; 0, 10, 20, 30 = Bran level (%); 29, 35 = Age in days

*Other variable costs per bird:-
- Mortality at 2%, costing K 150 per bird.
- Chicks at K 1,350
- Labour at K 333
- Veterinary costs at K 145
- Transport at K 222
- Litter at K 93

#Gross Margin = Revenue - Variable Costs, where Revenue is K 7,500 per live Arbor acres bird.

@Gross Margin % = $\frac{\text{Gross Margin}}{\text{Variable Costs}} \times 100$

APPENDIX G: REGRESSION ANALYSIS @FUNCTIONS FOR RELATIONSHIP BETWEEN NUTRIENT APPARENT DIGESTIBILITY AND MAIZE BRAN LEVEL UP TO 30%

APPENDIX G i): Arbor acres

$NUT	METHOD	*R^2/r^2	#R/r	df	F	Sigf	Std Error	bo	b_1	b_2
DM	LIN	0.897	-0.947	2	17.34	0.053	2.229	73.250	-4.150	
DM	QUAD	1.000	1.000	1	3841.40	0.011	0.112	74.825	-8.875	1.575
CP	LIN	0.570	-0.755	2	2.65	0.245	2.541	55.800	-1.850	
CP	QUAD	0.880	0.938	1	3.66	0.347	1.901	57.325	-6.425	1.525
EE	LIN	0.141	-0.375	2	0.33	0.625	2.187	80.590	-0.560	
EE	QUAD	0.896	0.947	1	4.33	0.322	1.073	79.140	3.790	-1.450
NDF	LIN	0.684	-0.827	2	4.33	0.173	8.280	42.340	-7.710	
NDF	QUAD	0.997	0.998	1	154.13	0.057	1.185	48.165	-25.185	5.825
Ca	LIN	0.136	-0.369	2	0.31	0.632	2.514	25.720	-0.630	
Ca	QUAD	0.136	0.369	1	0.08	0.930	3.555	25.695	0.550	0.025
P	LIN	0.270	-0.520	2	0.74	0.480	2.142	4.250	-0.825	
P	QUAD	0.998	0.999	1	223.18	0.047	0.168	5.765	-5.363	1.513
AME	LIN	0.541	-0.736	2	2.36	0.264	0.077	2.900	-0.053	
AME	QUAD	0.999	0.999	1	648.15	0.028	0.004	2.954	-0.217	0.055

@ $y = bo + b_1x + b_2x^2$, where :
y = Nutrient digestibility (%), and
x = maize bran level (%)
b_0 - b_2 = Regression coefficients of y on x

$ Nutrient

* R^2 = Multiple coefficient of Determination
r^2 = Coefficient of Determination`

# R = Multiple coefficient of Correlation
r = Coefficient of Linear Correlation

APPENDIX Gii): Cobb

$NUT	METHOD	*R^2/r^2	#R/r	df	F	Sigf	Std Error	bo	b_1	b_2
DM	LIN	0.924	-0.961	2	24.21	0.039	1.791	72.360	-3.940	
DM	QUAD	0.998	0.999	1	258.85	0.044	0.402	73.610	7.690	1.250
CP	LIN	0.761	-0.872	2	6.37	0.128	2.685	54.820	-3.030	
CP	QUAD	0.958	0.979	1	11.47	0.204	1.588	56.545	-8.205	1.725
EE	LIN	0.741	0.861	2	5.72	0.139	1.084	74.260	1.160	
EE	QUAD	0.957	0.978	1	11.08	0.208	0.626	74.960	0.940	0.700
NDF	LIN	0.910	-0.954	2	20.18	0.046	2.579	41.270	-5.180	
NDF	QUAD	0.998	0.999	1	217.64	0.048	0.581	43.070	10.580	1.800
Ca	LIN	0.087	0.294	2	0.19	0.705	6.749	17.470	1.320	
Ca	QUAD	0.651	0.807	1	0.93	0.591	5.903	21.220	-9.930	3.750
p	LIN	0.082	0.286	2	0.18	0.713	0.607	2.840	0.115	
P	QUAD	0.931	0.965	1	6.77	0.262	0.235	3.252	-1.123	0.413
AME	LIN	0.930	-0.965	2	26.59	0.036	0.028	2.898	-0.064	
AME	QUAD	1.000	1.000	1	1115.98	0.021	0.003	2.918	-0.122	0.020

@ $y = bo + b_1x + b_2x^2$, where :
y = Nutrient digestibility (%), and
x = maize bran level (%)
b_0 - b_2 = Regression coefficients of y on x

$ Nutrient

* R2 = Coefficient of Determination
r2 = Coefficient of

# R = Coefficient of Multiple Correlation
r = Coefficient of Linear Correlation