EVALUATION OF MUNGONGO NUT MEAL AS A SOURCE OF PROTEIN IN BROILER RATIONS

By

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DECLARATION

I, **SICECANI JUSTIN MWANGALA,** DECLARE THAT THIS DISSERTATION REPRESENTS MY OWN WORK AND THAT IT HAS NOT PREVIOUSLY BEEN SUBMITTED FOR A DEGREE AT THIS OR AT ANY OTHER UNIVERSITY.

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APPROVAL

This dissertation of **Mr. Sicecani Justin Mwangala** is approved as a fulfilling part of the requirement for the award of Master of Science in Animal Nutrition (Animal Science) by the University of Zambia.

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ABSTRACT

The potential of Mungongo *(Ricinodendron rautanenii* schinz*)* as a source of protein in broiler rations was investigated. In the first trial, Soybean-based and Mungongo-based diets were formulated and fed *ad libitum* to broilers for six weeks. The treatments were: SOY (Soybean alone); SOY + A (Soybean + methionine + lysine); MG (Mungongo alone); MG + A (Mungongo + methionine + lysine); MG + A + T (Mungongo + methionine + lysine + tryptophan). In the second trial the first three treatments in the first trial (SOY, SOY + A and MG) were reformulated, while three other treatments; HMG (Heat treated Mungongo alone), HMG + A (Heat –treated Mungongo + methionine + lysine), and HMG + A + T (Heat-treated Mungongo + methionine + lysine +tryptophan) were also formulated and fed for another six–week period. Mungongo meal was heated to 125°C for 15 minutes in an attempt to deactivate the supposedly present antinutritional factor, ricin. A Completely Randomized Design (CRD) with 5 treatments in the first trial, and 6 treatments in the second trial replicated 3 times was used. There were no significant differences in feed intake between birds on SOY and those on SOY + A in both trials. However, feed intake, live, dressed and carcass weights for birds on Soybean-based diets were higher than those for birds on Mungongo-based diets. Addition of amino acids, lysine and methionine, increased intake and improved the performance of birds on Mungongo diet in terms of live, dressed and carcass weights more when Mungongo was untreated by 502%, 507% and 571% respectively, while when heat–treated the performance was improved by 149%, 203% and 239% respectively.Addition of the amino acid, tryptophan, increased the performance of birds on Mungongo diet in

terms of live, dressed and carcass weights by 15%, 15% and 16% respectively, only when Mungongo was heat-treated, but reduced the performance of birds on Mungongo diet when it was untreated by 6%, 7% and 5%, respectively. Heat treating Mungongo increased the performance of birds in terms of live, dressed and carcass weights by 95%, 92% and 105% respectively. Feed Conversion Ratios (FCRs) for the treatments were in the order: MG > SOY > SOY +A > HMG > HMG +A + T > HMG + A during the second trial, while during the first trial the order was MG > SOY > MG + A + T > SOY + A > MG + A. Liver and gizzard weights expressed as percentages of carcass weights were higher in birds on Mungongo-based diets than those on soybean-based diets. Carcass crude protein percentages differed in the order: SOY + A > SOY > HMG + A + T > HMG + A >MG >HMG, whereas carcass fat percentages were in the order: MG > HMG > HMG + A > HMG + A + T > SOY > SOY +A. Mungongo-based carcasses had higher ($P \leq 0.05$) fat percentages. Carcass calcium and phosphorus percentages were in the same order: SOY + A > SOY > HMG + A + T > HMG + A >MG > HMG. Carcasses of birds fed Mungongo-based diets had lower ($P \leq 0.05$) ash percentages than those for birds fed Soybean-based diets. The order of carcass ash percentages was: SOY + A > SOY > HMG + A + T > HMG + A > HMG > MG. Mungongo nut meal can be used as a source of protein in broiler rations when it is untreated and supplemented with amino acids lysine and methionine (MG + A). However the performance of birds fed this diet in terms of live, dressed and carcass weights is not as good as that for birds fed Soybean based diet supplemented with the same amino acids lysine and methionine. Heat treating Mungongo and supplementing with amino acid tryptophan increased the performance

of birds fed Mungongo diet in terms of live, dressed and carcass weights, although this increase was not as good as the overall performance of birds fed untreated Mungongo supplemented with amino acids lysine and methionine and those fed Soybean based diets.

DEDICATION

To our daughter **Tinata Sicecani** and our son **Sitwala Sicecani**. To my lovely wife **Natasha Sanjase Sicecani** who has been my comforter. To God Almighty, the creator of heaven and earth, who makes all things possible.

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LIST OF ACRONYMS AND ABBREVIATIONS

MM	Maize meal
SBM	Soy bean meal
L/STONE	Lime stone meal
MET	Methionine
LYS	Lysine
TRPT	Tryptophan
B/Prex	Broiler Premix
MG	Mungongo meal alone
UNZA	University of Zambia
REQT	Requirement
E/D	Excess or Deficit
SI	Small Intestine
HMG	Heat-treated Mungongo alone
HMG+A	Heat-treated Mungongo with amino acids lysine and methionine
HMG+A+T	Heat-treated Mungongo with amino acids lysine, methionine and tryptophan
SOY	Soy bean alone
SOY+A	Soy bean with amino acids lysine and methionine
TRT	Treatment
WK	Week
Nobs	Number of observations
STD	Standard
Lvwt	Live weight
Drsdwt	Dressed weight
Livrwt	Liver weight
Gzdwt	Gizzard weight
Carcwt	Carcass weight
FI	Feed Intake
Fecwt	Fecal weight
Dgs CP	Digestible crude protein
Fec CP	Fecal crude protein
Dgs CF	Digestible crude fiber
Fthrwt	Feather weight

Trtrswt	Trotters weight
Moist	Moisture
Dstkwt	Drumstick weight
Thghwt	Thigh weight
Brstwt	Breast-bone weight

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CHAPTER I

1.0 INTRODUCTION

Monogastric livestock and human beings have similar qualitative nutrient requirements. In Zambia, oil seed crops are utilized by both humans and poultry as sources of dietary proteins. Among the oil seed crops used as protein sources in such rations, soybean meal is the most widely used. Unfortunately in Zambia, soybeans are the most expensive among the legume crops produced as they require to be intensively managed by use of pesticides, fungicides, inoculums and fertilizers. Consequently, most smallholder farmers in the country, especially the poor ones, can hardly afford including soybeans in rations for their animals. This, therefore, calls for Animal nutritionists to intensively research into the feeding values of alternative plant materials that are or potentially cheap and available locally. Such alternatives will not only reduce the cost of poultry feeds and products, but will also avail soybeans more for human consumption.

The need for alternative products that can be used as sources of protein in poultry rations has necessitated the consideration of tree nuts in the wild. Mungongo (*Ricinodendron rautanenii* Schinz) nut is one such alternative. This tree, known in Zambia as Mungongo (Lozi), Mukusu (Bemba), Mkusu (Nyanja), Muma (Tonga) or Ndubala (Kaonde), produces nuts with crude protein rivaling that of soybeans and other oil seed cakes. Therefore, from the protein content point of view, Mungongo theoretically can be used as a source of protein in broiler rations.

1.1 BACKGROUND INFORMATION

Mungongo (*Ricinodendron rautanenii* Schinz) tree occurs naturally in the southern and western parts of Zambia, including the Luangwa valley of Eastern Province. Occurrences in the northern part of Northern and Luapula provinces are believed to be the result of a later introduction. It is most frequent and occasionally dominant in the Kalahari sand woodlands but is also found in the Munga woodland, scrub mopane and lake basin of chipya. Outside Zambia, it grows in Angola, Namibia, Botswana and parts of the Democratic Republic of Congo, and Mozambique (Storrs, 1995).

Mungongo trees make an excellent 'live' fence and grow very vigorously from truncheons, cutting considerable time to fruit bearing, compared to the time it would take if they were grown from the seeds (Storrs, 1979). Estimated fruit yields of 200-800kg per hactre have been reported (Peters, 1987). The seed nut has oil content of up to 63% (Palmer and Pitman, 1972). The oil and the nuts are both said to be edible. However, the oil is especially suitable for paints and varnish manufacturing (Storrs, 1982). The nuts or kernels of the seeds of Mungongo are reported to have a protein content of 29%, and after the seed coats have been removed and some of the oil squeezed out mechanically, the protein of the resulting meal is reported to be about 40% (Palmer and Pitman, 1972).

In an experiment in which Mungongo nut meal was used as a protein source in broiler rations, Matauka (1992) reported higher mortality in chicks on Mungongo nut meal than those on Soybean meal. He also observed that the chicks on Mungongo meal had

stunted growth, the plumage was darker than that of chicks on Soybean meal and had generally performed poorly. Since the amino acid profile of the protein in Mungongo meal was not known, it was suggested that an amino acid imbalance in the meal may have had negatively affected the chicks' performance.

In late 1992, Mungongo meal samples were sent to Denmark for amino acid analysis. The analysis revealed that the amino acid profile was comparable to that of Soybean meal, except for amino acid tryptophan, which was found to be in immeasurable low quantities. An amino acid composition examination of experimental diets used by Daura and Matauka (Matauka, 1992) revealed that the essential amino acids methionine, lysine, and tryptophan were not in quantities meeting the chicks' requirement for optimal growth. Therefore, if supplemented with these limiting amino acids, Mungongo meal should theoretically be able to be used as a source of protein in broiler rations.

Considering the given background above, the question still remained as to why the chicks that were fed Mungongo-based rations in the experiment conducted by Daura and Matauka performed poorly. This prompted speculations on the probable causes. Questions were raised on whether the poor performance was due to the excess oil content of the Mungongo-based diets as a result of the inefficient method of extracting the oil from the nuts; or whether it was due to the amino acid imbalance caused by inadequate amounts of essential amino acids methionine, lysine, and tryptophan; or whether it was due to the presence of anti-nutritional factors in the

nut meal; or whether it was due to all the factors above. These speculations prompted the need for further research; hence, this experiment was carried out.

1.2 PROBLEM STATEMENT

The development and intensification of modern smallholder poultry production in Zambia has led to the evolution of confinement feeding systems of broilers and layers. These feeding systems are based on commercial feed compounded using the highly priced soybean meal as the source of protein. The high cost of soybean cake not only makes the poultry business unprofitable for most smallholder farmers, but also has choked the expansion of the poultry sector in the country. Therefore, use of alternative sources of protein in broiler rations, such as Mungongo, should be tried. However, from the research conducted by Daura and Matauka (Matauka, 1992), the birds on the diet with Mungongo as a source of protein performed poorly in terms of liveweight gains and survival rates. It is from this background that this research was conducted with the aim of assessing the potential of Mungongo nut as a protein source in broiler rations; and if the birds still performed poorly, investigate further the possible causes of the poor performance.

In this investigation, aspects which were not taken into consideration in the previous research (Matauka, 1992), such as minimization of the quantity of oil in the Mungongo meal, supplementing with essential amino acids methionine, lysine, and tryptophan that were in inadequate amounts, deactivation of antinutritional factors, especially ricin, supposedly present in Mungongo, were considered.

1.3 JUSTIFICATION OF THE STUDY

This study therefore investigated the feeding value of Mungongo (*Ricinodendron rautanenii* Schinz) tree nuts, as a possible source of protein in broiler rations. In Zambia, this tree grows in the wild and is available in most forests of the country. Mungongo nuts are as high in crude protein as Soybeans and therefore, the use of their meal as a possible alternative source of protein in broiler ration, not only has the potential to reduce the cost of poultry feeds and products but, would also avail soybeans more for human consumption. Consequently, more farmers would be encouraged to venture into poultry production, thereby contributing to the expansion of the poultry sector as a whole in Zambia.

1.4 OVERALL AIM OF THE STUDY

The overall aim of the study was to investigate the nutritive value of Mungongo nuts as a source of protein in broiler r ations so that they could be an alternative to soybeans.

1.5 OBJECTIVES OF THE STUDY

To meet the above aim, specific objectives listed below had to be achieved during this study.

a. To compare the performance of broiler birds fed rations compounded using oil-extracted Mungongo meal as a source of protein with those fed rations compounded using soybean meal.

b. To compare the performance of broiler birds fed rations compounded using Mungongo meal as a source of protein supplemented with essential amino acids methionine and lysine found not to be in adequate levels in Mungongo, with those fed rations compounded using soybean meal.

c. To compare the performance of broiler birds fed rations compounded using Mungongo meal as a source of protein supplemented in addition to essential amino acids methionine and lysine, with tryptophan which was found to be in inadequate quantities in Mungongo meal with those fed rations compounded using Mungongo meal supplemented with essential amino acids methionine and lysine without tryptophan.

d. To compare the performance of broiler birds fed rations compounded using heat-treated Mungongo meal as a source of protein with those fed rations compounded using untreated Mungongo meal.

e. To evaluate and compare the carcass composition of broilers fed Mungongo meal-based rations with those fed soybean meal-based rations.

CHAPTER II

2.0 LITERATURE REVIEW

2.1 CHARACTERISTICS OF MUNGONGO (*RICINODENDRON RAUTENENII*)

Mungongo is a tree that belongs to the Euphorbiaceae family in which cassava (*Manihot esculenta*) and castor beans (*Ricinus communis*) are (Palmer and Pitman, 1972; Purseglove, 1987). The tree is confined to Africa mostly, particularly south of the equator. It is distributed widely throughout southern Africa as it is found in Zambia, Democratic Republic of Congo (DRC), Angola, Namibia, Botswana, South Africa, Mozambique and Zimbabwe (Hans, Daka and Hang'andu, 1979). Largest belt of distribution extends from northern Namibia into northern Botswana, south west Zambia and western Zimbabwe. Another belt is in eastern Malawi and another in eastern Mozambique (Timberlake et al., 1993).

The tree is dioecious and deciduous, meaning that it can either be female or male and loses leaves during the dry season respectively (Palmer and Pitman, 1972). Its wood is whitish, soft, very light but durable. Although its texture is like that of wool, it is easier to work and stronger than more widely known balsa wood. It was used at one time to make particle board on a commercial scale, and a reasonable paper has been made from it on an experimental scale (Storrs 1995). Other uses include the making of masks, floats, dart and drawing boards, packaging cases, toys, coffins, drums and temporary canoes (Storrs 1995). The kernel is also used to enrich sauces to

accompany meat, fish and vegetables. Consumption increases in difficult times such as droughts and during civil war (Gregory et al., 2005).

The tree generally grows to a height of 7-12 m (Lee, 1973) although it may grow taller. Although the tree is generally considered rapid growing (Peters, 1987), it was designated a protected species in Namibia in the early 1990s in terms of the existing forest legislation since 1952 (Erkkila and Siiskonem 1992), probably because of its socio-economic importance. In Zambia, Chimbelu (1983) found that trees with short bole and many branches occurred on disturbed land where spacing between trees was wide. These trees also tended to yield more fruits. Limited data are available on yields although some estimates indicate yields of 200-1000 kilograms per hectare in Northern Namibia and in Angola (Keegan, 1982; Peters, 1987; Graz, 2002). In terms of vegetative propagation, some success seems to have been achieved with the planting of the truncheons. Chimbelu (1988) reported, for instance, that the Luchazi people of Zambia were familiar with the techniques of vegetation propagation. The tree can be propagated through single-node, leafy stem cuttings from juvenile trees (or coppice shoots) using low technology non-mist propagators (Leakey et al., 1990).

Fanshawe (1962); Palmer and Pitman (1972) reported that the tree produces fruits that are eaten by both humans and animals (wild and domesticated), which makes them valuable to the indigenous people of areas where it grows. The tree takes around 25 years to commence fruiting. The flowering of the trees is influenced by the local climatic variations. In southern Africa, they flower during the hot dry season which is around October to December. The fruits fall from the tree with the skin still green

(variably, April to May), and mature on the ground. There, the skin turns brown, and the flesh softens and develops full flavour. The trees lose their leaves every year towards the end of the season of autumn and winter (variably, about June to August), and it is at this time that the last of the ripe fruits fall. The fruits are drupaceous and ellipsoidal (keegan, 1982) approximately 35mm long and 25mm in diameter. The skin of the seed takes up to 10% of the fruit by volume, the flesh 20%. The remaining 70% is the seed, including the wide hard shell around it (Peters, 1987). Keegan (1982) reported the following percentages for the parts of the Mungongo fruit: exocarp - greater than 20%; endocarp - greater than 60%; testa plus nut - greater than 10%. Tane (1997) reported that the kernels were rich in fatty acids and crude protein. He reported that the fatty acids in seeds consist mainly of a high level of linoleic acid (60.32%), oleic acid (14.66%), stearic acid (12.95%) and palmitic acid (12.08%). The seeds have a high energy value of 35.58 kilojoules per gram of dry matter (Tiki-Manga et al., 2000).

2.1.1 NUTRITIONAL CONTENT OF THE KERNEL

Mungongo kernel ranges from 57% to 63% fat by weight. In addition to other components, about 43% of this fat is polyunsaturated fat (almost entirely linoleic acid), about 17% saturated fat (palmitic and stearic), and about 18% mono unsaturated oleic acid (Palmer and Pitman, 1972; Peters, 1987). According to Palmer and Pitman (1972), the oil is edible. However, according to Storrs (1982), the oil is especially suitable for paints and varnish manufacturing. The oil is also used in cooking when it is fresh. The paste of ground kernels is also used as a thickening agent for soups and stews (Fondoun et al., 1999). Mungongo oil is rich in

phytosterols. In cosmetics, the oil is used for its hydrating, regenerating and restructuring properties and ultra violet (uv) protection for hair and skin (Gunstone, 2002). Due to high gamma-tocopherol content in form of vitamin E (565 mg), the oil is very stable and doesn't oxidize into 'rancidity' for a very long time, even at high ambient temperatures.

The kernel has in the range of 26g to 29g of protein per 100g, an amount similar to peanuts and other protein rich legumes, and after the seed coat has been removed and some of the oil squeezed mechanically, the protein content of the resulting meal is above 40% (Palmer and Pitman, 1972; Peters, 1987). Defatted flour has been reported to contain even higher protein content, more than 8% nitrogen (i.e. more than 50% crude protein) and 16% ash (Tchiegang et al., 1997).

In terms of other nutrients, Mungongo kernel has, per 100g, approximately 193mg of calcium, 527mg magnesium, 3.7mg iron, 2.8mg copper, 4.0mg zinc, 0.3mg thiamine, 0.2mg riboflavin, 0.3mg nicotinic acid, no vitamin C (the flesh has about 15mg), and a stunning 565mg of vitamin E (almost entirely as gamma-tocopherol) (Peters, 1987; Taylor et al., 1995; Mapongmetsen and Tehiegang, 1996).

2.1.2 AMINO ACID PROFILE OF MUNGONGO MEAL

From the amino acid analysis of Mungongo meal samples that were sent to Denmark in late 1992, it was revealed that the amino acid profile was comparable to that of soybean meal, except for amino acid tryptophan, which was found to be in immeasurable quantities. Amino acid composition examination of experimental diets

used by Matauka (Matauka, 1992) revealed that the essential amino acids methionine, lysine, and tryptophan were not in quantities meeting the chicks' requirement for optimum growth.

An amino acid deficiency always is accompanied by slow growth, poor feathering and usually fat makes up a larger proportion of the carcass than in an adequately nourished chick (Leslie et al., 1972). The amino acids most difficult to supply in adequate amounts from feed protein ingredients are lysine and methionine plus cystine. In the case of Mungongo meal, in addition to the amino acids lysine and methionine plus cystine, the amino acid tryptophan, which was found to be in immeasurable quantities, should also be considered. These are sometimes referred to as critical amino acids because special attention must be given to meeting the birds' requirements for these amino acids when formulating rations.

Table 1: Amino acid profile (Courtesy of REKV. & AFD.T. Hvelplund. Afd. LAB. NR. 5706, Germany, 1992)

Amino acid*	Soybean meal (%) (mechanically extracted)	Soybean meal (%) (solvent extracted)	Mungongo meal
LYS	3.2	3.2	1.045
MET	0.7	0.6	0.805
TRP	0.7	0.7	0.000

Table 2: Amino acid profile of soybean (CULLISON, E.A, 1987)

Amino acid*	Soybean meal (%) (solvent extracted, 44%)
LYS	2.99
MET	0.58
TRP	0.71

*Amino Acid: LYS = Lysine; MET = Methionine; TRP = Tryptophan

2.2 NUTRITIONAL REQUIREMENTS OF GROWING BROILERS

The National Research Council (1995) recommends that during the first four weeks of growth, poultry feeds should contain 23% Crude protein; 3200 Kcal ME per kg of feed; 1% Calcium; 0.7% Phosphorus; 1.25% Lysine and 0.86% of Methionine plus cystine whereas during the finishing phase (4-8 weeks), broilers require finisher rations that contain 18 -20% Crude protein; 3200 Kcal ME per kg; 0.8% Calcium; 0.4% Phosphorus; 1.09% Lysine and 0.8% Methionine plus cystine (Kekeocha, 1995).

Smith and Waldroup (1988), in their experiment to estimate tryptophan requirement of male broiler chicks, suggested from their results that tryptophan requirement of the young (0 to 21 days old) broiler chickens was no greater than 0.16% of a diet containing 3200 k cal ME per kilogram. From another experiment in which the 'available' tryptophan requirements of male and female broiler chicks were determined at 7- day intervals from 0 to 56 days, using a diet-dilution technique, the tryptophan requirements were 2.4g (males) and 2.2g (females) per kilogram of diet from 0 to 7 days, and 1.7g per kilogram (males and females) from 7 to 35 and 36 to 56 days. The absolute requirement of the chicks for tryptophan increased with age and was higher for male than for female birds (Freeman, 1979). However, Church and Pond (1988), observed that these requirements varied with chickens' breed, presence of toxicants in the diet and the chicken's productivity. Energy and protein requirements are also affected by prevailing climatic conditions (Virk *et al.*, 1978).

Ensminger and Olentine (1978) stated that amino acids that make up proteins are really the essential nutrients in a poultry diet rather than the protein molecule as a whole. Therefore, crude protein content as a measure of the nutritional value of feed is not as accurate as its amino acid profile. Methionine is particularly growth depressing at high levels (Harper et al., 1970).

Ensminger *et al.* (1978), ARC (1975) and Re'rat (1972) said that the other feed nutrient characteristics that determine intake are the energy/amino acids ratios. Chickens generally eat to meet their energy requirement (Ensiminger and Olentine, 1978). If the feed has low energy content, the birds will eat more of it in order to meet the energy levels required in their bodies. Calcium deficiency symptoms include among others, retardation of growth, decreased feed consumption and osteoporosis or low calcium rickets. 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).

2.3 METHIONINE, LYSINE AND TRYPTOPHAN METABOLISM IN CHICKENS

Methionine deficiency is always accompanied by slow growth, poor feathering and usually fat makes up a larger proportion of the carcass than in an adequately nourished chick (Leslie et al., 1972). Shea *et al.* (1990) indicated that dietary tryptophan supplementation could have a sedating effect, hence birds would be more

docile. Dietary tryptophan supplementation also resulted in less energy expenditure for activity, hence better feed conversion. Tryptophan is also a precursor for serotonin and melatonin and niacin. Both serotonin and melatonin are claimed to have 'sedative' effects on animals. If birds are docile and spend less energy (hence reduced oxygen needs) on physical activity, it is hypothesized that this would improve performance and reduce mortality ascribed to ascites. Tryptophan is an essential amino acid for chickens and has many metabolic roles. From the work by Rosa and Pest (2001), it was concluded that the National Research Council (1980) estimate of tryptophan requirement (0.2% of the diet) is probably low. At least 0.25% tryptophan is necessary to maximize feed efficiency.

Lysine is accepted as the second most limiting amino acid in diets based on corn and soybean meal in monogastric animals. Lysine is needed for optimizing breast meat yield (Jackson *et al.,* 1989). From their experiment, Jackson *et al.* (1989) noted that lysine was a component of enzymes and had a special importance in the formation of the cartilage tissue and in the ossification. As a component of nucleotides in the cell nucleus, lysine stimulates cellular division. Lysine is involved in a number of metabolic processes. For broilers there is an increase in feed conversion and in carcass quality of the birds when lysine levels are adequate. Lysine is also very important in protein synthesis and feathering.

The essential amino acid methionine plays four key roles in vertebrate metabolism. First as an essential amino acid, second as a precursor of cystine, third as a key

intermediate in methyl group transfer, and fourth, in polyamine synthesis (Wallis, 1999). In an experiment to determine the sulphur amino acid requirement of broilers from 3 to 6 weeks of age (Jensen et al., 1989), it was observed that methionine supplementation significantly improved body weight gain and feed efficiency.

From the results of another experiment where the influence of dietary protein level on the broiler chicken's response to methionine supplements was investigated (Garcia et al., 2000), it was concluded that methionine supplements improved performance of chicks that were fed 24% Crude protein, as was indicated by body weight gain and Feed Conversion Ratio (FCR). Methionine supplementation decreased relative liver size and increased breast muscle protein. Methionine supplements also increased the feather weight of the chicks. Similarly, Laufey and Fisher (1971), in their study on Castor bean meal (CBM) as a protein source for chickens, concluded that supplementing CBM with both lysine and tryptophan gave growth rates of chicks as good as those obtained with Methionine supplemented isolated soybean protein.

It is against this background that during this experiment, supplementation with the essential amino acids methionine, lysine and tryptophan that were in inadequate amounts in Mungongo meal was done as a strategy to improve the performance of the birds.

2.4 EFFECT OF DIETARY FAT (OIL) ON CHICKEN PERFORMANCE

Chickens generally eat to meet their energy requirement (Ensiminger and Olentine, 1978); hence the energy content of the feed controls their feed intake. If a feed has a low energy content, birds will eat more of it in order to meet the energy levels required in their bodies. Scott et al. (1982), 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 such that growth may cease entirely. Diets with small energy: protein ratios promote lean broiler carcasses (Donaldson, 1956; Thomas and Combs, 1967). In a feeding trial conducted by Matauka (1992), Mungongo-based rations had higher energy content than those that were based on Soybean meal as a source of protein and the feed intake of birds on Mungongo-based rations was low. The high energy content of Mungongo-based rations was attributed to the high oil content of the Mungongo kernels.

In this research, a special improvised manual machine that functioned with the help of a hydraulic jack (see **figure 1**) was used to ensure that the oil extraction process was more efficient. The extracted oil was more than 30% higher by volume as compared to what was extracted during the research by Matauka (1992).

2.5 PROBABLE ANTI NUTRITIONAL FACTOR RICIN IN MUNGONGO

In the Euphorbiaceae family in which Castor beans and Mungongo belong (Palmer and Pitman, 1972; Purseglove, 1987), the anti-nutritional factor of concern is ricin. Ricin is a protein toxin which acts as a cellular poison found in high concentration in

the Castor bean (*Ricinus communis*). Ricin also contains highly toxic glycol-proteins that cause cell death. It is found in all plants from the species *Ricinus communis* (Behl et al., 1986).

Lectins, of which ricin is an example, are proteins which agglutinate red blood cells and are capable of damaging intestinal mucosa. The biological effects of lectins probably result from their affinity for sugars. They may bind to the carbohydrate moieties of cells of the intestinal wall and cause a non-specific interference with nutrient absorption (Liener, 1985). In Fodder trees, lectins of interest are robin and ricin (Kumar, 2003). In contrast to other proteins, lectins resist digestive breakdown (D'Mello, 2000). Ricin toxin consists of an enzymatically active 'A' and 'B' chains with lectin properties (Olsnes and Pihl, 1973). The A chain enters the cytosol and inactivates ribosomes by deprivation of a single adenosine residue in 285 ribosomal RNA (Endo *et al., 1987).* The B chain binds to galactose-containing surface receptors. The 'B'chain makes a channel through the vacuole cell wall, allowing the A chain to enter the cytoplasm and reach the ribosomes where it blocks protein synthesis and kills the cell. One molecule of ricin is sufficient to kill one cell. Previous research in which digestibility measurements were performed in rats fed a diet containing small amounts of isolated black bean lectin has shown that there was low food absorption and nitrogen retention in these animals due to reduced glucose absorption and inhibition of protein synthesis in a cell-free system by inactivating some components essential for the elongation of peptides (Jaffe, 1950). Therefore, it became necessary in this research that measures were taken to try and deactivate the

supposedly present ricin in Mungongo meal to see if the birds would improve their performance.

2.5.1 DEACTIVATION OF RICIN

Exposure to high or very warm temperatures or high humidity will diminish the strength of the toxin ricin. Ricin in the process becomes inactive and therefore Mungongo meal should be efficiently utilized as a source of protein in broiler rations. This is called denaturing effect.

In line with this, Okorie and Anugwa (1987), in their research on the effect of roasted and non roasted castor beans on growing chicks' performance reported that all birds on castor beans had reduced feed intake and weight gain, and increased feed conversion ratio, with the most dramatic effects found in birds fed the non-roasted castor beans from which 83% of the birds died during the experimental period. Meanwhile mortality was not significantly increased for birds fed the roasted beans. Roasting was performed to deactivate ricin, but ricin content of the diets was not determined. Similarly, Gardener et al. (1960), Kakade and Evans (1965), and Bender (1983), in their researches on detoxification and deallerginisation of castor beans, nutritive value of navy beans, and hemagglutinins in beans, respectively, reported that the nutritive value of many legumes was enhanced by autoclaving but preliminary soaking before autoclaving was also effective. In another experiment in which detoxification in Castor beam meal was done (Springer Berlin and Heidelberg, 1949), ricin was denatured by autoclaving for 15 minutes at 125^{o} C. They concluded that the

denaturing process completely destroyed ricin with minimal changes in physical character of the meal. Rudolph et al. (1949), in their study on the detoxification of castor seed pomace which showed acute oral toxicity for the rat and chick, reported the acute toxicity to be destroyed by various physical and chemical treatments designed to denature the toxic protein constituent, ricin. The best physical treatment that produced essentially complete destruction of ricin with minimal changes in the physical character of the pomace was autoclaving for 15 minutes at 125° C.

In view of this, instead of autoclaving due to lack of equipment, an attempt was made during this experiment to deactivate ricin by heating Mungongo meal in the oven at 125° C for 15 minutes. Ricin was never measured in the Mungongo meal, but since Mungongo tree belongs to the Euphorbiaceae family in which Castor beans belong (Palmer and Pitman, 1972), it was logical to assume that ricin was present in Mungongo meal. From the foregoing discussions on the interventions taken in order to examine the speculations on the causes of poor performance of birds that were fed Mungongo rations by Matauka (1992), there is enough reason to suggest that Mungongo meal can be used as a source of protein in broiler rations. This is the reason why this experiment was conducted to prove these suggestions or assertions. The research sought to determine whether there would be differences in the performance between birds on oil extracted, amino acid supplemented, ricin free Mungongo meal and that of birds on soybean meal.

CHAPTER III

3.0 MATERIALS AND METHODS

A total of three hundred and sixty (360) day-old Ross broiler chicks were reared in poultry houses at the University of Zambia, School of Agricultural Sciences Field Station. These broilers were reared in two separate trials. One hundred and eighty (180) chicks were reared during the first trial of the experiment whereas the other One hundred and eighty (180) were reared during the second trial of the experiment.

3.1 PRE-REARING HISTORY AND PREPARATION OF POULTRY HOUSES

Two weeks before the chicks arrived, the rearing area of the Poultry houses were cleaned and disinfected (i.e., during both trials). Later, the windows were covered with black polythene plastic sheets to keep wind draughts out as well as assist in regulating temperatures inside the buildings. One square-meter pens were erected using mesh wire dividers and the concrete floor covered with wood shavings as bedding. The wood shavings were regularly turned and changed to ensure they remained dry.

3.2 PROCESSING OF MUNGONGO NUTS INTO A MIXABLE MEAL

In order to have Mungongo nuts into a mixable meal, oil was mechanically extracted from the nuts by means of an improvised machine shown in the picture (**Figure 1**).

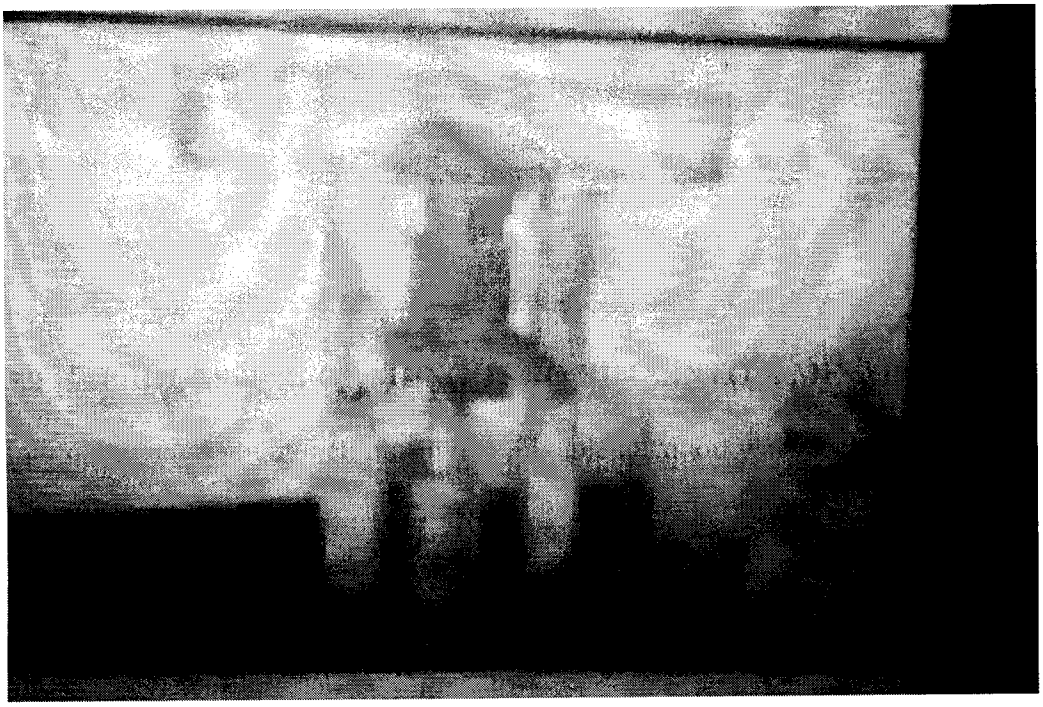


Figure 1: Oil extraction machine

The above machine was made of railway line steel pillars which held a metal plate onto which a cylinder shaped extractor lay. Using the hydraulic jack placed underneath the metal plate, a steel piston pressed the nuts down the extractor, hence oil flowed on the sides and then collected in a bottle. Thereafter, the oil-extracted nuts were taken to the School of Mines for grinding using a stone crusher. The ground meal was then sieved through 1mm size sieves and the Mungongo meal was collected and put in 50kg bags. Required quantities of dicalcium phosphate, limestone, broiler premix, methionine, lysine, tryptophan and salt were weighed and mixed with the main feed ingredients Maize, Soybean or Mungongo meals.

3.3 FEED INGREDIENTS AND FEED FORMULATIONS

Five basic formulations were fed to the experimental birds during the first trial of the research, whilst 6 formulations were fed to the experimental birds during the second trial. A starter formulation having 22% crude protein was fed to the birds for the first 4 weeks in both the trials. Thereafter, a finisher formulation containing 18% crude protein was fed to the birds up to the end of the 6^{th} week. A digestibility trial was carried out during week 7 of the second trial.

3.3.1 FEED INGREDIENTS USED IN THE RESEARCH

Most of the feed ingredients were purchased from Livestock Cooperative Services limited company in Lusaka Show Grounds within Lusaka, except for the Mungongo which was purchased from the rural areas in Senanga District of Western Province of Zambia, and Maize which was bought from Liempe farm belonging to the University of Zambia. The list of ingredients that were used in the formulations together with the places where they were sourced is indicated in Table 1.

Table 3: Feed ingredients used in both trials and their sources

No.	Ingredient	Source
1.	Maize	Liempe UNZA Farm
2.	Soybean meal	Livestock Services Ltd
3.	Mungongo	Senanga rural district
4.	Dicalcium Phosphate	Livestock Services Ltd
5.	Limestone	"
6.	Broiler Premix	"
7.	Salt	"
8.	Lysine	"
9.	Methionine	"
10.	Tryptophan	France (Europe)

3.3.2 FEED FORMULATIONS

3.3.2.1. STARTER FORMULATIONS

The Zambia Bureau of Standards guidelines (ZS 017:2000) recommended a broiler starter diet having a minimum of 22% crude protein and a corresponding minimum energy content of 2870 kcal/kg. In this experiment, the Soybean based starter formulations constituted 22% CP, 3039 Kcal ME/kg, 1% Ca, 0.45% P, 0.5% salt, 0.3% premix, 1.25% lysine and 0.92% Methionine whereas Mungongo based starter formulations constituted 22% CP, 3140 Kcal ME/kg, 1% Ca, 0.45% P, 0.5% salt, 0.3% premix, 1.25% lysine, 0.92% methionine and 0.23% tryptophan as presented in tables 2 and 3 respectively.

Table 4: Nutrient content of ingredients (Soybean based)

		Ingredients used as sources of nutrients								
Nutrient	**Reqt**	**MM**	**SBM**	**DCP**	**L/STN**	**LYS**	**MET**	**Salt**	**B/prex**	**Tot**
CP%	22	5.01	16.99	-	-	-	-	-	-	22
ME kcal/kg	2870	1802	1237	-	-	-	-	-	-	3039
Ca%	1.00	0.01*	0.12*	0.40	0.60	-	-	-	-	1.00
P%	0.45	0.054[b]	0.084[b]	0.31	-	-	-	-	-	0.45
NaCl%	0.5	-	-	-	-	-	-	0.5	-	0.5
B/Prex%	0.3	-	-	-	-	-	-	-	0.3	0.3
LYS%	1.25	0.02	0.56	-	-	0.67	-	-	-	1.25
MET%	0.92	0.04	0.39	-	-	-	0.49	-	-	0.92
Ration (Kg)	**100**	**56.32**	**38.68**	**1.71**	**1.58**	**0.67**	**0.49**	**0.5**	**0.3**	**100.25**

NB: *Ca is not available to poultry (Ensminger *et al.*, 1990)

[b] P is available at 33% (Ensminger *et al.*, 1990)

NUT=Nutrient REQT=Requirement E/D=Excess or deficiency TOT=Total MM=Maizemeal SYM=Soybean meal DCP=Dicalcium phosphate

LSM=Limestone meal LYS=Lysine

MET=Methionine B/prex = Broiler premix

P% av=Available phosphorus

Table 5: Nutrient content of ingredients (Mungongo based)

		Ingredients used as sources of nutrients									
Nutrient	**Reqt**	**MM**	**MG**	**DCP**	**L/STN**	**TRPT**	**LYS**	**MET**	**Salt**	**B/Prex**	**Tot**
CP%	22	4.42	17.58	-	-	-	-	-	-	-	22.0
ME kcal/kg	2870	1690	1450	-	-	-	-	-	-	-	3140
Ca%	1.00	0.01*	0.09*	0.38	0.62	-	-	-	-	-	1.00
P%	0.45	0.05[b]	0.11[b]	0.29	-	-	-	-	-	-	0.45
NaCl%	0.5	-	-	-	-	-	-	-	0.5	-	0.5
B/Prex%	0.3	-	-	-	-	-	-	-	-	0.3	0.3
LYS%	1.25	0.01	0.18	-	-	-	1.05	-	-	-	1.24
MET%	0.92	0.03	0.56	-	-	-	-	0.32	-	-	0.91
TRPT%	0.23	0.02	0.00	-	-	0.21	-	-	-	-	0.23
Ration (Kg)	**100**	**49.69**	**45.31**	**1.71**	**1.58**	**0.21**	**1.05**	**0.32**	**0.5**	**0.3**	**100.67**

NB: *Ca is not available to poultry (Ensminger *et al.*, 1990)

[b]P is available at 33% (Ensminger *et al.*, 1990)

3.3.2.2. FINISHER FORMULATIONS

The Zambia Bureau of Standard guidelines (ZS 017:2000) recommended a broiler finisher diet having a minimum of 18% crude protein and a corresponding energy content of 3100 kcal/kg. In this experiment, the Soybean based finisher formulations constituted 18% CP, 2939 Kcal ME/kg, 0.8% Ca, 0.35% P, 0.5% salt, 0.3% premix, 0.86% lysine and 0.61% Methionine, whereas Mungongo based finisher formulations constituted 18% CP, 3048 Kcal ME/kg, 0.8% Ca, 0.35% P, 0.5% salt, 0.3% premix, 0.86% lysine, 0.61% methionine and 0.173% tryptophan as presented in tables 4 and 5 respectively.

Table 6: Nutrient content of ingredients (Soybean based)

		Ingredients used as sources of nutrients								
Nutrient	**Reqt**	**MM**	**SBM**	**DCP**	**L/STN**	**LYS**	**MET**	**Salt**	**B/prex**	**Tot**
CP%	18	6.03	11.97	-	-	-	-	-	-	18
ME kcal/kg	3100	2067	872	-	-	-	-	-	-	2939
Ca%	0.8	0.01*	0.08*	0.29	0.51	-	-	-	-	0.80
P%	0.35	0.07[b]	0.06[b]	0.23	-	-	-	-	-	0.35
NaCl%	0.5	-	-	-	-	-	-	0.5	-	0.5
B/Prex%	0.3	-	-	-	-	-	-	-	0.3	0.3
LYS%	0.85	0.02	0.40	-	-	0.44	-	-	-	0.86
MET%	0.60	0.05	0.28	-	-	-	0.28	-	-	0.61
Ration (Kg)	**100**	**67.74**	**27.26**	**1.24**	**1.34**	**0.44**	**0.28**	**0.5**	**0.3**	**99.10**

NB: *Ca is not available to poultry (Ensminger *et al.*, 1990)

[b] P is available at 33% (Ensminger *et al.*, 1990)

Table 7: Nutrient content of ingredients (Mungongo based)

		Ingredients used as sources of nutrients									
Nutrient	**Reqt**	**MM**	**MG**	**DCP**	**L/STN**	**TRPT**	**LYS**	**MET**	**Salt**	**B/Prex**	**Total**
CP%	18	5.61	12.39	-	-	-	-	-	-	18.00	18.00
ME k cal/kg	3100	2018	1030	-	-	-	-	-	-	3048	3048
Ca%	0.8	0.01*	0.06*	0.27	0.53	-	-	-	-	0.8	0.8
P%	0.35	0.06[b]	0.08[b]	0.21	-	-	-	-	-	0.35	0.35
NaCl%	0.5	-	-	-	-	-	-	0.5	-	0.5	0.5
B/Prex%	0.3	-	-	-	-	-	-	-	0.3	0.3	0.3
LYS%	0.85	0.02	0.13	-	-	-	0.71	-	-	0.86	0.86
MET%	0.6	0.05	0.21	-	-	-	-	-	-	0.61	0.61
TRPT%	17	0.003	0.00	-	-	0.17	-	-	-	0.173	0.173
Ration (kg)	**100**	**63.07**	**31.93**	**1.24**	**1.34**	**0.17**	**0.71**	**0.5**	**0.3**	**99.61**	**99.61**

NB: *Ca is not available to poultry (Ensminger *et al.*, 1990)

[b]P is available at 33% (Ensminger *et al.*, 1990)

3.4 EXPERIMENTAL DESIGN, TREATMENTS AND UNITS

3.4.1 EXPERIMENTAL DESIGN

The feeding trials were carried out in a Completely Randomized Design (CRD). There were 5 treatments each replicated 3 times during the first trial of the experiment, whereas during the second trial, 6 treatments were used and each was replicated 3 times.

3.4.2 TREATMENTS

During the first trial of the experiment, Soybean based rations were two and they included treatment 1, a ration with amino acids methionine and lysine supplementation (SOY+A); treatment 2 which was a Soybean alone ration, without amino acid supplementation (SOY). Mungongo-based treatments were three and they

included treatments 3, 4 and 5. Treatment 3 was Mungongo-based ration with amino acids methionine and lysine supplementation (MG+A). Treatment 4 was Mungongo-based ration with amino acids methionine, lysine and tryptophan supplementation (MG+A+T). Treatment 5 was Mungongo alone ration, without amino acid supplementation (MG).

During the second trial, the Soybean based rations 1 and 2 were reformulated. Mungongo based rations 3 and 4 were reformulated as well, but with heat-treated Mungongo meal. Mungongo alone ration or treatment 5 was reformulated just like it was during the first trial. The sixth ration or treatment 6, which was actually treatment 5 during the first trial but now with heat-treated Mungongo meal, was also formulated.

The composition of Soybean based rations that were used in the experiment is presented in tables 6 and 7, whereas that of Mungongo based rations is presented in tables 8, 9 and 10.

COMPOSITION OF SOYABEAN BASED STARTER AND FINISHER RATIONS

Table 8: Treatment 1 (Composition of Soybean with amino acids Methionine and lysine)

Ingredient	Starter (kg)	Finisher (kg)
MM	56.32	67.74
SBM	38.68	27.26
DCP	1.71	1.24
L/STONE	1.58	1.34
MET	0.49	0.24
LYS	0.67	0.44
B/Prex	0.30	0.30
Salt	0.50	0.30
Total	**100.25**	**99.10**

Table 9: Treatment 2 (Composition of Soybean alone without amino acids)

Ingredient	Starter (kg)	Finisher (kg)
MM	56.32	67.74
SBM	38.68	27.26
DCP	1.71	1.24
L/STONE	1.58	1.34
MET	0.00	0.00
LYS	0.00	0.00
TRPT	0.00	0.00
B/Prex	0.30	0.30
Salt	0.50	0.50
Total	**99.09**	**98.38**

NB: MM = Maize Meal SYM = Soybeans meal DCP = Dicalcium Phosphate

L/stone = Lime stone Met = Methionine Lys = Lysine

Trpt = Tryptophan B/Prex = Broiler Premix MGM = Mungongo meal

COMPOSITION OF MUNGONGO BASED STARTER AND FINISHER RATIONS

Table 10: Treatment 3 (Composition of Mungongo with amino acids Methionine and lysine)

Ingredient	Starter (kg)	Finisher(kg)
MM	49.69	**63.07**
MG	45.31	31.93
DCP	1.61	1.16
L/STONE	1.63	1.39
MET	0.32	0.35
LYS	1.05	0.71
B/Prex	0.30	0.30
Salt	0.50	0.50
Total	**100.41**	**99.41**

Table 11: Treatment 4: Composition of Mungongo with amino acids Methionine, lysine and tryptophan)

Ingredient	Starter (kg)	Finisher (kg)
MM	**49.69**	**63.07**
MG	45.31	31.93
DCP	1.61	1.16
L/STONE	1.63	1.39
MET	0.32	0.35
LYS	1.05	0.71
TRPT	0.21	0.17
B/Prex	0.30	0.30
Salt	0.50	0.50
Total	**100.25**	**99.58**

Table 12: Treatment 5 (Mungongo alone without amino acids)

Ingredient	Starter (kg)	Finisher(kg)
MM	49.69	63.07
MG	45.31	31.93
DCP	1.61	1.16
L/STONE	1.63	1.39
MET	0.00	0.00
LYS	0.00	0.00
TRPT	0.00	0.00
B/Prex	0.30	0.30
Salt	0.50	0.50
Total	**99.04**	**98.35**

3.4.3 EXPERIMENTAL UNITS

During the first trial, each of the 5 treatments was replicated 3 times making a total of 15 experimental units. Twelve (12) birds were used in each experimental unit. During the second trial, each of the 6 treatments was replicated 3 times making a total of 18 experimental units with ten (10) birds per experimental unit.

3.5 BIRD MANAGEMENT

During the experimental period for both trials, drinkers and feeders were cleaned daily. Heaters and 250 watt infra-red bulbs were used as sources of heat for the birds during the first 4 weeks. A footbath with Microl disinfectant was maintained at the entrance. The solution was changed regularly to ensure that the concentration was maintained. Both feed and water were supplied to the chickens *ad libitum* throughout the study during both trials. Stress pack and an antibiotic vitamin and mineral supplement (Alfaceryl) were administered to provide for the mineral and vitamin requirement and also to reduce the possibilities of disease outbreak and cross

infections. Gumboro vaccine was administered in water on the 10^{th} day and 21^{st} day, while on the 14^{th} day, Newcastle (lasota) vaccine was administered during both trials. Each pen had a drinker and an adult-bird tubular feeder. Weighed feed was placed in feeders. Over filling of feeders was avoided to minimize spillage. Black plastic sheets that were placed over the windows protected the birds at night from night chills. During the day when it was hot, the plastic sheets were opened to allow for proper ventilation.

3.6 DIGESTIBILITY TRIALS

After the end of the second trial, a digestibility trial was conducted. Three birds were randomly selected, one from each of the 3 replicates of the 6 treatments. Hence, a total of 18 birds were selected and put in pens. The birds were given their respective experimental diets. The feed was weighed before putting into the feeders and after the birds had eaten to determine the amount of feed that was consumed during that period. Feces were collected on a daily basis throughout that 7 day-period. The total feces collected in each pen were weighed and dried in an oven at $105^{o}C$ for 24 hours to determine the moisture and dry matter. After that, they were packed in labeled plastics. The feces were used to determine crude protein and crude fibre in the experimental diets that were digested by the birds.

3.7 DATA COLLECTED

3.7.1 LIVEWEIGHTS

Chicks were weighed on a weekly basis from the day of arrival or the start of research. The weighing was done on the same day of the week and at the same time

of the day, to determine the average liveweight at the beginning of the experiment and at the end. Liveweight gains from the first week to the sixth week were recorded.

3.7.2 FEED CONSUMPTION

Feed intake was determined on a weekly basis and a digital scale was used to weigh the feed. The feed intake was taken as the difference between the amount of feed given within the week and the remaining feed at the end of the week. This was done on the same day of the week together with weighing of the individual birds.

3.7.3 MORTALITY RATE

Mortalities were recorded during the research period for both trials. The number of birds that died and possible causes of deaths were recorded up to the end of the trial. The causes of death were determined by Laboratory analysis at the School of Veterinary Services, University of Zambia.

3.7.4 CHEMICAL COMPOSITION ANALYSES

Samples from the Maize, Soybean and Mungongo meals that were used in the ration formulations were each analyzed for dry matter (DM), crude protein (CP), calcium (Ca) and phosphorus (P) contents using AOAC (1998) procedures. Samples from starter ration formulations were also analyzed for CP, Ash, Ca and P contents as the correct levels of these nutrients are very important for optimum muscle and bone tissue development in early growth. Samples from finisher ration formulations and

fecal samples from digestibility trial were analyzed for DM, CP, EE, Ash, Ca, P, and crude fibre (CF). All samples were analyzed in duplicates.

3.7.5 CARCASS CHARACTERISTICS AND YIELD EVALUATION

At the end of the first trial of the research, three (3) birds were randomly selected from each treatment and dressed for carcass yield evaluation. The selected chickens were weighed, slaughtered and scalded with hot water to facilitate hand plucking of feathers. Average slaughter weights, average dressed weights, dressing percentages of the carcasses were noted. Upon evisceration and removal of offals from the carcasses, average empty weights were recorded. Drumsticks, thighs and breast meat were weighed in each treatment in order to determine their average weights.

3.7.6 CARCASS PROXIMATE CHEMICAL COMPOSITION

At the end of the second trial, three half carcasses from each treatment were freeze dried until constant dry weights were obtained for proximate chemical composition determination. The dry meat was ground and analyzed for percentages of ash, crude protein (CP), ether extract (EE), calcium (Ca) and phosphorus (P). Results were compared among the treatments to check for significant variations.

3.8 STATISTICAL ANALYSIS

3.8.1 STATISTICAL PACKAGE USED IN ANALYSIS

The Statistical Analysis System (SAS 6.12 windows version) was the scientific statistical computer software that was used to analyze the collected data.

3.8.2 ANALYSIS OF VARIANCE (ANOVA)

Using SAS system, Analysis of Variance (ANOVA) was done for liveweight, feed intake and carcass characteristics in order to find out if there were significant differences among the treatment mean values. Duncan's Multiple Range Test (DMRT) was used to separate means according to Little and Hills (1978) and Gomez and Gomez (1984).

CHAPTER IV

4.0 RESULTS AND DISCUSSION

4.1 FIRST TRIAL

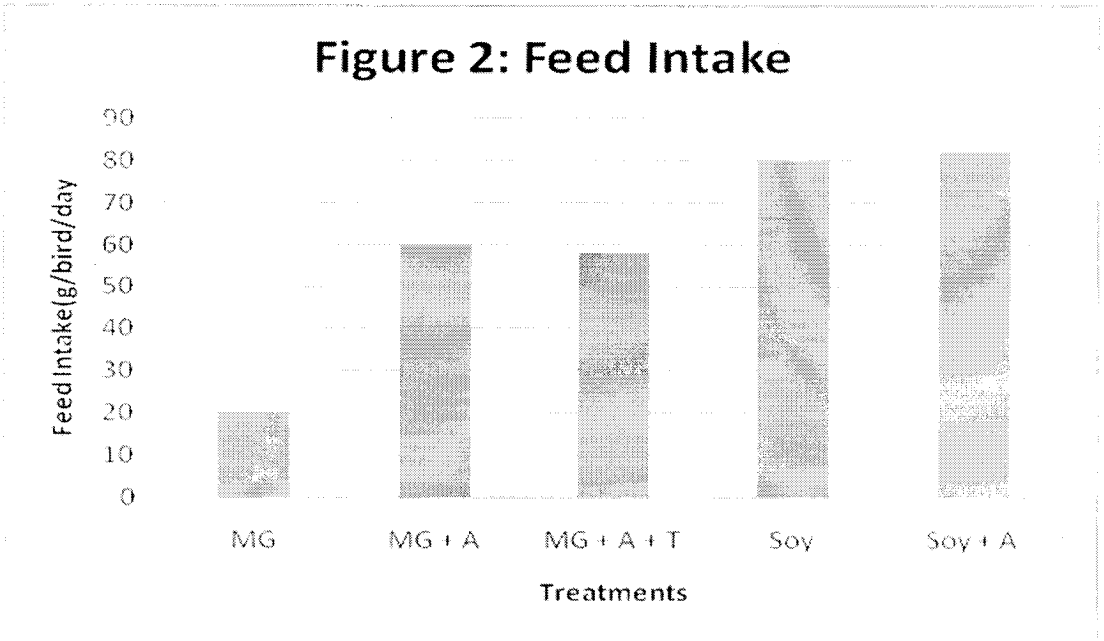
4.1.1 Effect of treatments on feed intake and liveweights

The mean values of feed intake and carcass composition for birds fed different diets based on either Mungongo or soybean meal as a source of protein during the first trial are presented in Table 13.

4.1.2 Feed intake

There were no significant differences in feed intake between birds on SOY (79.1g) and those on SOY + A (81.3g) during the first trial. The intakes of birds on soybean-based diets were higher than for birds on Mungongo-based diets. This may imply that Soybean-based diets were more palatable than Mungongo-based diets. This reduced feed intake is reflected in the reduced live weights, carcass and dressed weights recorded on the Mungongo-based diets. Addition of amino acids lysine and methionine to Mungongo based diets increased feed intake by 202% whereas when these two amino acids were added to Soybean alone (SOY) intake was increased by 2.8% only. This suggests that even though the levels of these two amino acids in Mungongo are as in Soybean (Daura, unpublished), they were not as available to the birds to stimulate intake as they were in Soybean meal. A further addition of tryptophan, however, reduced feed intake by 5%, although this reduction was not significant. A possible reason for this reduction could be that tryptophan interfered with one of the amino acids lysine or methionine or both. Birds on MG ate the lowest

amounts of feed (19.7g), suggesting that the Mungongo alone treatment was less palatable, perhaps because of the supposedly presence of an antinutritional factor, ricin.



4.1.3 Live weight

Birds on SOY (Soybean alone) treatment with a mean live weight of 1942.3g were 578.4% heavier ($P \leq 0.0001$) than those on MG (Mungongo alone) which had a mean liveweight of 286.3g. Birds on SOY + A (Soyabean + methionine + lysine) had the highest mean live weight of 2388.0g, while those on MG + A (Mungongo + methionine + lysine) weighed 1724.0g on average. Birds on SOY + A were significantly heavier than those on SOY and all the Mungongo-based diets. Birds on MG + A were heavier ($P<0.0001$) than those on MG by 502%, but were not different ($P>0.05$) from those on MG + A + T. Addition of tryptophan to MG + A, however did not improve the performance of the birds in terms of liveweight, in fact, it decreased liveweights by 6.4%. Liveweights differed in the order: SOY + A > SOY

> MG + A > MG + A+ T > MG. Protein and amino acid deficiency could have resulted in low liveweights of birds on Mungongo-based diets. This conclusion is in line with the findings of Leslie et al. (1972) who reported that Amino acid deficiency resulted in slow growth, poor feathering and that fat usually made up a larger proportion of the carcass than in adequately nourished chicks. The birds on Mungongo-based rations had low feed intakes and liveweights. This poor performance is in agreement with Church and Pond (1988) who stated that signs of protein deficiency included reduced growth rate and reduced efficiency of feed utilization.

Ricin, which could have been present in Mungongo, may have inhibited absorption of nutrients, hence the low liveweights of birds. The increase in weights of birds on SOY diet after supplementation with amino acids methionine and lysine was 23%, whereas when birds on MG diet were supplemented with the same amino acids (methionine and lysine) the increase was 502%. The amino acid profile of Mungongo in terms of methionine and lysine (8.05g/kg and 10.45g/kg respectively) compared with soybean (7.61g/kg and 9.88g/kg respectively) suggests the possibility of inhibition of methionine and lysine from contributing to performance in Mungongo-based diets. The fact that there was a far much greater increase in weight (502%) upon addition of amino acids methionine and lysine to Mungongo than when the same amino acids were added to soybean (23%) indicates that, though the two amino acids in Mungongo are in amounts comparable to the levels in soybean (Daura, unpublished), they are not available for utilization by the birds. There seems to be factors present in Mungongo that inhibit their utilization. One probable factor is ricin.

Ricin is a lectin and according to Liener (1985), lectins bind to the carbohydrate moieties of cells of the intestinal wall and cause a non-specific interference with nutrient absorption. Therefore, birds on Mungongo alone may have experienced this non- specific nutrient absorption interference and failed to utilize the methionine and lysine in Mungongo, hence the low performance observed on Mungongo alone treatment. Further addition of the amino acid tryptophan to treatment MG + A to make the treatment MG +A +T resulted in a reduction of mean liveweights of the birds by 6%. This reduction could have been due to tryptophan interfering with either lysine or methionine or both. Shea et al. (1990) indicated that supplementation with tryptophan has a sedating effect which makes birds docile, resulting in less energy expenditure and more weight gain. Addition of tryptophan in this study had a negative effect on mean live weight of birds which is in contradiction with the findings of Shea et al. (1990).

Table 13: Effect of treatments on feed intake, liveweight, dressed weight, carcass weight and carcass characteristics

Trt*	Feed Intake (g/bird/ day)	Lvwt (g)	Fthrwt (g)	Fthrwt as % of lvwt (%)	Drsdwt (g)	Drsdwt as % of lvwt (%)	Carcwt (g)	Carcwt as % of lvwt (%)	Brstwt (g)	Brst wt as % of carcwt (%)
SOY	a 79.1	b 1942.3	b 172.6	a 8.8	b 1769.7	a 91.1	b 1488.0	a 76.7	b 273.3	b 18.4
SOY +A	a 81.3	a 2388.0	a 188.7	b 7.9	a 2199.3	a 92.1	a 1845.0	a 77.3	a 416.0	a 22.5
MG	c 19.7	d 286.3	e 25.6	a 8.9	d 260.7	a 91.1	d 193.7	b 67.7	e 13.7	c 7.1
MG +A	b 59.4	b,c 1724.0	c 142.3	a,b 8.3	b,c 1581.7	a 91.7	b,c 1299.3	a 75.4	c 248.3	b 19.1
MG+A +T	b 56.7	c 1613.0	d 136.7	a,b 8.5	c 1476.3	a 91.5	c 1238.3	a 76.8	d 222.7	b 18.0

[a, b, c, d] values in the same column with different superscripts are different (P≤0.05).

* Treatments: SOY = Soybean alone; SOY + A = Soybean + methionine + lysine; MG = Mungongo alone; MG + A = Mungongo + methionine + lysine; MG + A + T = Mungongo + methionine + lysine + tryptophan.

4.1.4 Carcass Weights, Carcass Weight as Percentage of liveweight, breast weights and breast weight as percentage of carcass weight

Birds on Mungongo-based diets had lighter carcasses than those on soybean-based diets. Significant differences existed in carcass weights among birds on the different treatments except between MG + A and MG + A + T. The present results are similar to those obtained by Matauka (1992) who reported that broilers on Mungongo-based diets had lower carcass weights and live weights than those on soybean-based diets. Carcass weights of birds on SOY + A were higher ($P \leq 0.01$) than for those on SOY. Birds on MG (193.7g) had carcasses 571% lower than those for birds fed MG + A (1299.3g), which were not significantly different from the carcasses of birds fed MG + A + T (1238.3g). These trends are similar to those found for liveweights. The huge increase in carcass weights for birds on MG + A over those for birds on Mungongo alone (MG) seems to be indicative of the big role played by the amino acids lysine and methionine in promoting tissue synthesis and deposition. The lack of this deposition in birds on Mungongo without supplemental lysine and methionine suggests that these amino acids are tied up in Mungongo. This is supported by the fact that carcasses of birds on soybean alone diet only increased by 24% when Soybean diet was supplemented with lysine and methionine (SOY + A). The amino acids methionine and lysine which apparently are tied up in Mungongo nut could be inhibited by ricin suspected to be present in Mungongo. Olsnes and Pihl (1973) concluded that ricin has both 'A' and 'B' chains. 'A' inactivates ribosomes in cytosol by depriving one adenosine residue in 285 ribosomal RNA. Therefore, this blocks

protein synthesis and kills the cell, hence the probable reason for low carcass and dressed weights on Mungongo-based diets.

There were no significant differences in carcass weight as a percentage of liveweight among treatments SOY (76.7%), SOY+A (77.3%), MG+A (75.4%), and MG+A+T (76.8%). Only birds on Mungongo alone treatment recorded carcass weights expressed as a percentage of their liveweights (67.7%) that were significantly lower than for all the other treatments. One of the contributing factors to this is most likely the poor development of the breast in these birds. This part of the carcass constituted only 7.1% of the carcass weight, while the values for the other treatments ranged from 18% to 22.5%. This could be attributed to the poor and inadequate supply of lysine for breast muscle development. Lysine is reported to be a major contributing amino acid to breast meat yield optimization (Jackson et al., 1989). From their experiment, Jackson and friends (1989) noted that lysine had a special importance in the formation of cartilage tissue and in the ossification. Lysine is very important in protein synthesis and feathering. From our experiment, there were significant differences ($P \leq 0.05$) in breast weights among all the treatments. The highest mean value was from birds that were fed SOY+A (416.0g) whereas the least value was recorded from birds that were fed MG (13.7g). In terms of breast weight as percentage of carcass weight, there were no significant differences among the birds on treatments SOY, MG+A, and MG+A+T. However, birds on SOY+A (22.5%) were significantly higher ($P \leq 0.01$) than those on all the other treatments, while birds on MG (7.1%) had the least breast weights as proportions of their carcasses.

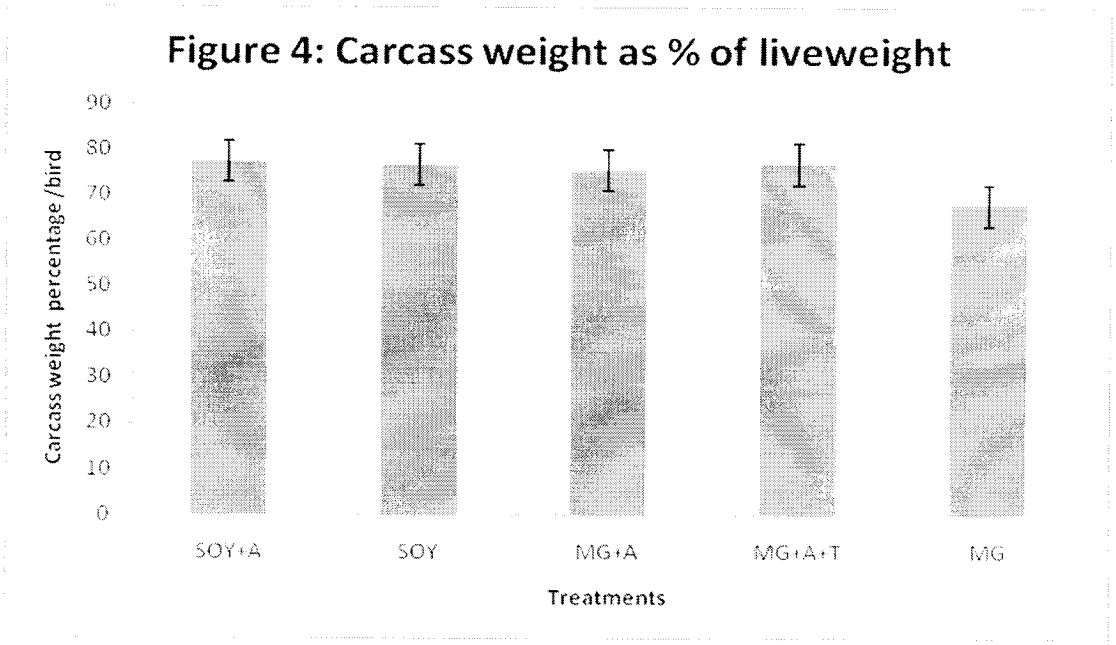
Addition of amino acids lysine and methionine to MG increased the breast weight by 1712%. This suggests that these amino acids were then available to the birds for tissue formation, especially the breast.

4.1.5 Dressed weights, Feather weights, dressed and feather weights as percentages of liveweight.

Birds on Mungongo-based diets generally had lower dressed weights than those that were fed Soybean-based diets. The highest dressed weights were recorded on treatment SOY + A, while the lowest were recorded on Mungongo alone (MG). Birds on SOY + A had higher ($P \leq 0.01$) dressed weights than those on SOY. Birds on MG had lower ($P \leq 0.01$) dressed weights than those on MG + A, which were not significantly different from those for birds fed MG + A + T and those for birds fed SOY. The heavier birds fed soybean-based diets produced heavier dressed carcasses. Addition of tryptophan reduced the dressed weight by 6.7% from 1581.7g to 1476.3g. The lower mean carcass and dressed weights for birds on Mungongo-based rations can be attributed to the lower mean liveweigthts. When the dressed weights were expressed as percentages of their respective liveweights, there were no differences among treatments.

There were differences ($P \leq 0.05$) in the feather weights among the different treatments. The highest mean value was recorded from birds on SOY+A (188.7g), whereas the lowest was from birds on MG (25.6g). In terms of feather weight expressed as a percentage of liveweight, the percentage for birds on treatments SOY (8.8%), MG (8.9%), MG+A (8.3%), and MG+A+T (8.5%) were not different. Those for birds on all the Mungongo-based diets were equally not different from one another. Only birds on SOY + A treatment had feather weight as a percentage of liveweight significantly lower than for all the other treatments. There were no significant differences among all the treatments in terms of dressed weights as percentages of liveweights, but in terms of carcass weight as a percentage of live weight, birds on Mungongo alone diet had a significantly lower mean value. This means that feather production on all the treatments was not different, but what

differed was the intestines and other internal organs that were removed when determining the carcass weight. Carcasses constituted the lowest proportion for birds on MG compared with the other treatments, thus the low carcass weight expressed as percentage of liveweight for birds on MG.



4.2 FEED CONVERSION RATIO (FCR)

Birds on Mungongo alone (MG) had the best FCR, indicating that Mungongo alone was the worst feed in terms of birds converting feed to tissue. This means that the amino acids in Mungongo alone were not readily available to the birds for digestion and consequently utilization. Possibly they were inhibited by some factors, most likely, ricin, hence the poor feed conversion and poor performance of these birds. Addition of amino acids lysine and methionine reduced the FCR by 51.7%, but a

further addition of tryptophan increased FCR by 7.1%, suggesting that tryptophan could have interfered with either methionine or lysine or both.

Table 14: Mean values of Feed Conversion Ratio (FCR) for birds on different treatments

Treatment*	FCR
SOY	1.7^{b}
SOY + A	1.4^{c}
MG	2.9^{a}
MG + A	1.4^{c}
MG + A + T	1.5^{c}

[a, b, c] values in the same column with different superscripts are significantly different ($P \leq 0.05$).

* Treatments: SOY = Soybean alone; SOY + A = Soybean + methionine + Lysine; MG = Mungongo alone; MG + A = Mungongo + methionine + lysine; MG + A + T = Mungongo + methionine + lysine + tryptophan

CHAPTER V

5.0 RESULTS AND DISCUSSION

5.1 SECOND TRIAL

5.1.1 Effect of Treatments on Feed intake, liveweight, dressed weight and carcass characteristics

The effects of the different treatment diets on intake, liveweights, dressed weights and carcass characteristics during the second trial of the research are presented in Table 15.

5.1.2 Feed intake

There were significant differences ($P \leq 0.0001$) in feed intake among all the treatments. Generally, birds on Soybean-based diets ate more than those on Mungongo-based diets and appeared to have had a higher ability for digestion and absorption of nutrients as evidenced by the higher digestibility of crude protein. Heat-treating Mungongo increased feed intake by 35.3%. Addition of amino acids lysine and methionine to heat-treated Mungongo further increased feed intake by 12.2%, suggesting that heat-treatment could have made the feed more palatable than untreated Mungongo. Addition of tryptophan further increased feed intake by 136%. Shea et al. (1990) indicated that supplementation with tryptophan has a sedating effect which makes birds more docile resulting in less energy expenditure, high intake and more weight gain. Addition of tryptophan could have increased the palatability of the Mungongo diet and thus it was consumed more by the birds. The low feed intake of birds that were fed MG was reflected by the low live, carcass and dressed weights recorded on this treatment. From the observed results, heat-treating Mungongo

improved feed intake by the birds. When lysine and methionine were added to untreated Mungongo in the first trial, the feed intake increased by 202%, but when the same amino acids were added to heat-treated Mungongo feed intake increased by 12% only. This could be so because probably heat-treating Mungongo denatured these supplementary amino acids. This seems to indicate that the amino acids lysine and methionine in raw Mungongo meal were tied up. When supplementary lysine and Methionine were added, it is these that elicited the observed increase in intake. Heat treating Mungongo must have liberated some of the lysine and Methionine tied up in raw Mungongo. Hence just heat treating Mungongo meal resulted in 35.3% increase in intake. Adding lysine and Methionine to heat-treated Mungongo (HMG) increased intake by 12%.

Figure 5: Feed Intake

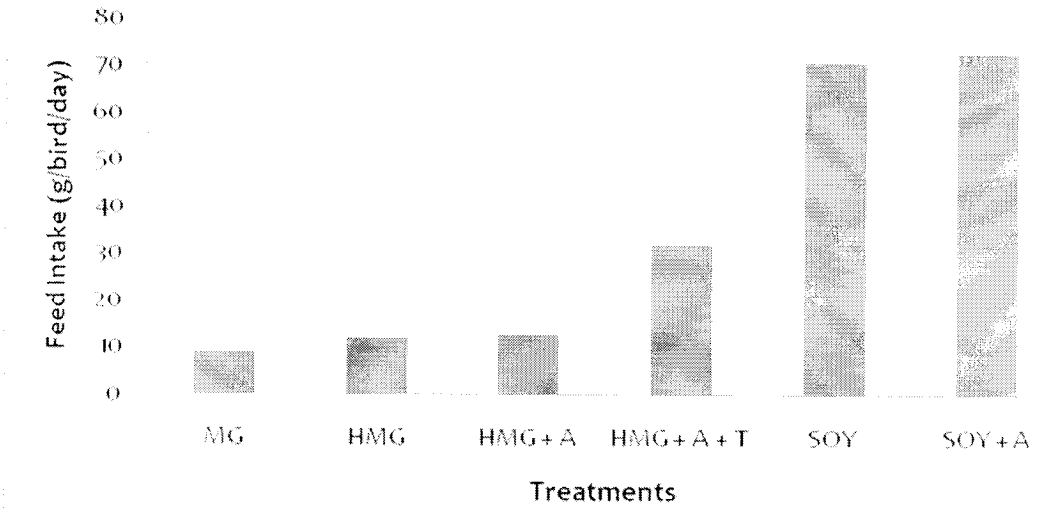


Table 15: Effect of treatments on feed intake, liveweight, dressed weight and carcass characteristics

Trt*	Feed Intake (g/bird/day)	Lvwt (g)	Fthrwt (g)	Fthrwt as % of lvwt (%)	Drsd wt (g)	Drsd wt as % of lvwt (%)	Carcwt (g)	Carcwt as % of lvwt (%)	Livrwt (g)	Livrwt as % of carcwt (%)	Gzd wt (g)	Gzd wt as % of carcwt (%)
SOY	b 71.0	b 1692.3	b 217.6	d 12.9	b 1474.7	a 87.1	b 1167.0	a 68.9	b 55.3	c 4.7	b 65.7	d 5.6
SOY + A	a 73.3	a 2138.3	a 301.0	d 14.1	a 1837.3	b 85.9	a 1454.0	a 68.0	a 66.7	c 4.6	a 90.7	d 6.2
MG	f 8.5	d 172.7	f 54.7	b 31.7	d 118.0	d 68.3	d 72.7	d 42.2	d 6.3	a 8.7	c 14.7	a 20.2
HMG	e 11.5	d 337.7	e 112.0	a 33.2	d 225.7	d 66.8	d 149.0	c 44.1	d 13.3	a 8.2	c 21.7	b 14.6
HMG +A	d 12.9	c 839.3	d 155.6	c 18.5	c 683.7	c 81.5	c 505.3	b 60.2	c 30.7	b 6.1	b 47.7	c 9.4
HMG +A +T	c 30.5	c 962.3	c 177.3	c 18.4	c 785.0	c 81.6	c 583.7	b 60.6	c 34.7	b 5.9	b 50.0	c 8.6

[a, b, c, d, e, f] values in the same column with superscripts are different (P≤0.05).

***Treatment:** SOY = Soybean alone; SOY + A = Soybean + methionine + lysine; MG = Mungongo alone; HMG = Heat-treated Mungongo alone; HMG+A = Heat-treated Mungongo+ methionine + lysine; HMG+A+T = Heat-treated Mungongo + methionine + lysine + tryptophan

5.1.3 Liveweights

Birds on SOY had a higher mean liveweight of 1692.3g than those on HMG which had a mean liveweight of 337.7g. Birds on SOY + A had the highest mean liveweight of 2138.3g, while those on HMG + A weighed 839.33g on average. Due to higher crude protein digestibility (Table 16), birds fed Soybean-based diets utilized the amino acids in Soybean and also channeled the supplemented amino acids lysine and methionine more for tissue synthesis and metabolism, hence more live, dressed and carcass weights. Birds on HMG + A, were heavier than those on MG by 386%. Heat-treating Mungongo improved the liveweight by 96% from 172.7g to 337.7g, but this was not significant. Addition of amino acids methionine and lysine to heat-treated Mungongo made a significant difference ($P \leq 0.01$) in terms of mean liveweight, increasing liveweight by 149%. A further supplementation with tryptophan to treatment HMG + A increased liveweight from 839.3g to 962.3g though this increase was not significant. This is in agreement with Shea and friends who indicated that supplementation with tryptophan result in less energy expenditure and more weight gain (Shea et al., 1990). Supplementary tryptophan could have been interfering with one of the amino acids lysine or methionine or both in untreated Mungongo but heat-treating Mungongo may have prevented the reaction between one of them or both, hence the slight improvement in performance when Mungongo meal is heat-treated compared with the observed decline when the nut meal is not heat-treated. Birds on HMG were heavier than those on MG by 96%. This suggests that ricin in Mungongo may have been deactivated. Liveweights differed in the order: SOY + A > SOY > HMG + A + T > HMG + A > HMG > MG.

5.1.4 Carcass weights, carcass weight as percentage of liveweights, liverweights, liverweight as percentage of carcass weights, gizzard weights, gizzard weight as percentage of carcass weights

Heat-treating Mungongo improved carcass weight from 72.7g to 149.0g, an increase of 105%. Addition of tryptophan to heat-treated Mungongo with amino acids methionine and lysine increased carcass weight by 16%. Dressed and carcass weights differed in the order: SOY + A > SOY > HMG + A + T > HMG + A > HMG > MG. In terms of carcass weight as a percentage of liveweight there were significant differences ($P<0.05$) among treatments. Addition of amino acids lysine and methionine to heat-treated Mungongo significantly improved the carcass weight expressed as a percentage of liveweight by 16.1%. With the addition of tryptophan, the increase was by 0.4%. The high values of liver and gizzard weights as percentages of carcass weights for birds on Mungongo diets suggest that the livers and gizzards for these birds could have been less efficient in their functions of detoxification and digestion respectively and thus the birds tried hard to survive.

There were no significant differences in liver and gizzard weights as percentages of carcass weights among the two Soybean-based diets and the two Mungongo-based diets with amino acid supplementation. In terms of gizzard weight as percentage of carcass weight, there were significant differences ($P\leq 0.05$) among the treatments with the trend being similar to that of liver weight as percentage of carcass weights. There was a significant difference between birds on HMG (14.6%) and those on MG (20.2%). Heat treating Mungongo therefore had a significant effect ($P\leq 0.05$) on gizzard weight as percentage of carcass weights of

the birds, implying that heat treating Mungongo improved the gizzard efficiency in breaking down feed. The low liver and Gizzard weight as percentages of carcass weights in birds on soybean-based diets suggest that the livers and gizzards for these birds performed their functions normally.

Figure 6: Liver weight as % of carcass weight

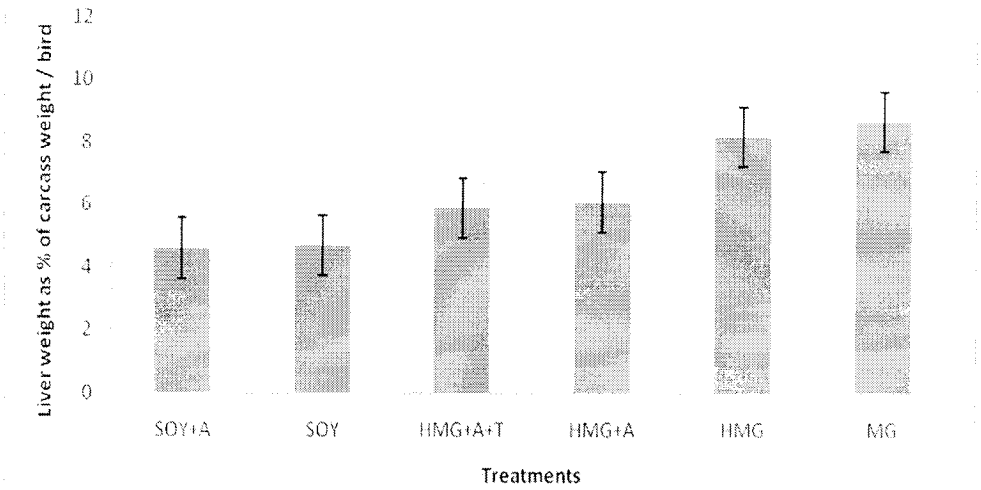
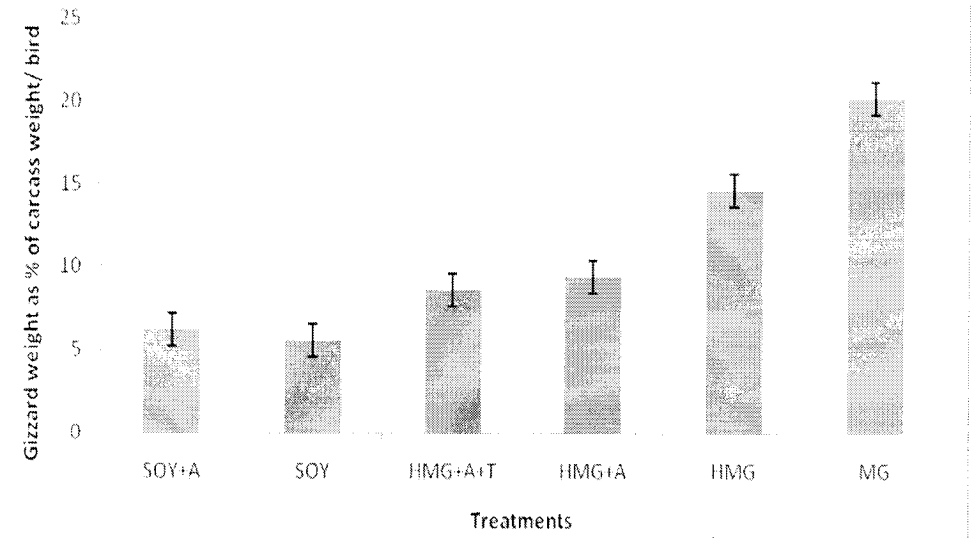


Figure 7: Gizzard weight as % of carcass weight



5.1.5 Dressed weights and dressed weight as percentage of liveweight

Heat-treating Mungongo had no significant effect on the dressed weight of the birds even though there was an increase in the dressed weight of 91.3% from 118g (MG) to 225.7g (HMG). The addition of tryptophan to heat-treated Mungongo + methionine + lysine (HMG + A) did not have a significant effect on dressed weights although birds increased their dressed weights by 14.8%. Birds on HMG + A had a significant ($P \leq 0.01$) increase in dressed weight of 203% when compared to those on HMG. Dressed weights of birds on both soybean-based diets were higher than those for the birds on Mungongo-based diets. Birds on soybean-based diets had higher dressed weights expressed as percentages of their liveweights than those on Mungongo-based diets. Birds on MG and HMG had the lowest values although heat treating Mungongo reduced this value by 2.2%.

5.1.6 Feather weights and Feather weights as percentages of liveweights

The weights of feathers for birds on different treatments followed the pattern of values for liveweights. Birds on Soybean-based diets had feathers that weighed more than those for birds on Mungongo-based diets. However, with regards to feather weight as a percentage of liveweights, birds on Mungongo-based diets had higher mean values than those on Soybean-based diets; with the highest value being recorded for birds on HMG (33.2%) followed by those on MG (31.7%). This implies that birds on Mungongo-based diets channeled most of their protein for making feathers rather than converting it to meat. This is reflected by the low carcass as a percentage of liveweight for these treatments (Table 13).

5.2 FEED CONVERSION RATIO (FCR)

Birds on MG (Mungongo alone) had a higher ($P \leq 0.05$) FCR (2.1) than those on SOY (Soybean alone) which had 1.8. The lower the FCR, the better utilized the feed is. Heat-treating Mungongo resulted in a significant improvement in FCR from 2.1 to 1.4. Addition of amino acids methionine and lysine resulted in further reduction of FCR (from 1.4 to 0.6). This decrease in FCR could mean that addition of methionine and lysine improved the efficiency of the feed utilization and hence high feed intake which resulted in more of this feed being converted into tissue. As a result, liveweights also increased. This is because lysine is important in protein synthesis. These results agree with Church and Pond, 1988 who suggested that diets that promote a high rate of gain will result in a greater efficiency than diets that do not allow such rapid gain. The increase in FCR from 0.6 to 1.3 when tryptophan was added could have been due to amino acid antagonism or interference of tryptophan with either methionine or lysine or even both. However, birds on HMG + A + T whose FCR was 1.3 had a better feed conversion ratio than those on HMG whose FCR was 1.4. This agrees with the conclusion by Shea et al. (1990) who indicated that dietary tryptophan supplementation results in better feed conversion. Generally, tryptophan has positive effects on feed intake. The greater feed intake leads to increased growth performance and improved FCR. Heat-treatment of Mungongo could have deactivated the antinutritional factor ricin and may have resulted in a more balanced supply of amino acids being available for synthesis of tissue protein. With the exception of birds on Mungongo alone, those on other treatments were generally better converters of the feed eaten into meat.

Table 16: Mean values of Feed Conversion Ratio (FCR) for birds on different treatments.

Treatment *	FCR
SOY	1.8^{b}
SOY + A	1.4^{c}
MG	2.1^{a}
HMG	1.4^{c}
HMG +A	0.6^{d}
HMG +A +T	1.3^{c}

$^{a, b, c, d}$ values in the same column with different superscripts are different ($P<0.05$)

*Treatments: SOY = Soybean alone; SOY + A = Soybean + methionine + lysine; MG = Mungongo alone; HMG = Heat-treated Mungongo alone; HMG+A = Heat-treated Mungongo + methionine + lysine; HMG+A+T = Heat-treated Mungongo + methionine + lysine + tryptophan.

5.3 CARCASS COMPOSITION

Addition of amino acids methionine and lysine to SOY (Soybean alone) resulted in an increase in carcass crude protein percentage of 1.4% from 60.8% (SOY) to 62.2% (SOY + A). There were no significant differences in carcass crude protein percentage between heat-treated Mungongo alone (50.0%) and untreated Mungongo alone (50.2%). Addition of amino acids methionine and lysine to heat-treated Mungongo did not have a significant effect on carcass crude protein percentage, although the addition slightly improved the crude protein percentage from 50.0% to 50.6%. Further addition of tryptophan to heat-treated Mungongo with amino acids methionine and lysine significantly increased the crude protein percentage from 50.6% to 53.9%, an increase of 3.3%. Carcass crude protein percentages of birds on soybean-based diets were significantly higher ($P \leq 0.05$) than those of birds on Mungongo-based diets (Table 15). Carcass crude protein percentages differed in the order: SOY + A > SOY > HMG + A + T > HMG + A > MG > HMG

Carcasses with high protein content (soybean-based) had low fat content, but had high ash content. Birds on Mungongo-based diets had more fat in their carcasses and had decreased proportions of carcass protein and ash. The results obtained in this study agree with those of Tulloh (1964) that showed that carcass composition was associated with the amount of fat, which, in turn was affected by body weight. In terms of Carcass ether extract percentages there were no significant differences among the treatments MG (37.1%), HMG (37.0%) and HMG+A (36.8%). Addition of tryptophan to heat-treated Mungongo + methionine + lysine, reduced the ether extract percentage from 36.8% to 34.8%. This reduction

could be attributed to an increase in protein content upon addition of tryptophan. High protein content results in low fat content. Carcasses of birds on soybean-based diets had significantly ($P \leq 0.05$) lower ether extract percentages than those on Mungongo-based diets (Table 15). This apparently is a reflection of the high fat content of Mungongo-based diets. Ether extract percentages were in the order: MG > HMG> HMG + A > HMG + A + T > SOY > SOY + A.

Table 17: Effect of treatments on carcass composition

Treatment *	Crude Protein (%)	Ether Extract (%)	Calcium (%)	Phosphorus (%)	Ash (%)
SOY	60.8^{b}	30.9^{c}	3.7^{a}	2.1^{b}	12.8^{a}
SOY + A	62.2^{a}	28.3^{d}	3.7^{a}	2.3^{a}	12.9^{a}
MG	50.2^{d}	37.0^{a}	2.3^{c}	1.6$^{c, d}$	8.3^{d}
HMG	50.0^{d}	37.1^{a}	2.2^{c}	1.5^{d}	9.3^{c}
HMG +A	50.6^{d}	36.8^{a}	2.4^{c}	1.7^{c}	11.3^{b}
HMG +A +T	53.9^{c}	34.8^{b}	2.8^{b}	2.0^{b}	12.6^{a}

$^{a, b, c, d}$ values in the same column with different superscripts are different ($P \leq 0.05$)

***Treatments:** SOY = Soybean alone; SOY + A = Soybean + methionine +lysine; MG = Mungongo alone; HMG = Heat-treated Mungongo alone; HMG+A = Heat-treated Mungongo + methionine + lysine; HMG+A+T = Heat-treated Mungongo + methionine + lysine + tryptophan.

Carcasses of birds on Mungongo-based diets were lower ($P<0.05$) than those of birds on soybean-based diets in terms of ash percentage. This reduction could be due to high carcass ether extract percentages of these birds (Table 17). Addition of amino acids methionine and lysine increased the ash percentage from 12.8% for SOY to 12.9% for SOY + A. There was an increase in ash and Crude protein contents but a decrease in ether extract content. Heat treating Mungongo increased the ash percentage by 1.0%. Addition of amino acids methionine and lysine to heat-treated Mungongo significantly increased the ash percentage by 2.0%, and a further addition of tryptophan increased the ash content by 1.3%. Carcasses of birds fed Mungongo-based diet had lower ($P\leq0.05$) ash percentages than those of birds fed Soybean-based diets. The order of the carcass ash percentages was: SOY + A > SOY > HMG + A + T > HMG + A > HMG > MG. Variations in carcass ash content may be attributed to differences in fat content. Fat deposits contain virtually no calcium, thus, birds with carcasses high in fat like those fed Mungongo-based diets recorded lower percentages of ash.

There were no significant differences in calcium percentage between the carcasses of birds on the two soybean-based diets. Heat-treating Mungongo and addition of amino acids methionine and lysine did not have any significant effects on carcass calcium percentage. Addition of tryptophan to heat-treated Mungongo + methionine + lysine increased the level of calcium significantly ($P\leq0.05$) by 0.4%. The calcium percentages of carcasses of birds on soybean-based diets were significantly higher ($P\leq0.05$) than those for carcasses of birds on Mungongo-based diets

In terms of carcass phosphorus percentages, there were no significant differences between carcasses of birds on heat-treated Mungongo-based diet (HMG; 1.5%) and untreated Mungongo-based diet alone (MG; 1.6%). Addition of amino acids methionine and lysine to heat-treated Mungongo and also the addition of tryptophan to heat-treated Mungongo + methionine + lysine increased the levels of phosphorus in the carcasses of birds by 0.2% and 0.3% respectively. Calcium and phosphorus percentages were in the same order: SOY + A > SOY > HMG + A + T > HMG + A > MG > HMG.

5.4 CRUDE PROTEIN DIGESTIBILITY IN DIETARY TREATMENTS

Birds that were fed Soybean diets appear to have a generally higher ability for digestion and consequently utilization of amino acids lysine and methionine as evidenced by higher digestibility of crude protein (Table 18). This partly explains the lower FCRs for the birds on soybean-based diets as compared with those on Mungongo-based diets.

Table 18: Crude protein digestibility of dietary treatments

Treatment *	Feed Intake (g/week)	Crude Protein Digestibility (%)
SOY	588.0^{b}	86.0^{b}
SOY + A	827.0^{a}	94.9^{a}
MG	235.0^{c}	71.6^{d}
HMG	328.0^{c}	80.4^{c}
HMG +A	359.0^{c}	85.9^{b}
HMG +A +T	335.0^{c}	$83.4^{b,c}$

$^{a, b, c, d}$ values in the same column with different superscripts are different ($P \leq 0.01$).

*Treatments: SOY= Soybean alone; SOY + A = Soybean+ methionine + lysine; MG = Mungongo alone; HMG = Heat-treated Mungongo alone; HMG + A = Heat-treated Mungongo + methionine + lysine; HMG + A + T = Heat-treated Mungongo + methionine + lysine + tryptophan.

5.5 MORTALITY RATE

During the first trial, a total of four birds died from treatment MG (Mungongo alone). One died in the first week and one in the fifth week, probably because of the effects of the supposedly present antinutritional factor ricin. The other two died in the sixth week and were taken to the School of Veterinary Medicine, department of Clinical Studies laboratory where they were diagnosed of suspected ascites. 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). This is primarily caused by increased oxygen demand in the rapidly developing broilers and a forced increase in output of blood by the heart (Julian, 1993; Windeman and Bottje, 1993). During the second trial, there were no deaths suggesting that heat treating Mungongo could have eliminated the above mentioned possible cause of mortality.

CHAPTER VI

6.0 SUMMARY AND CONCLUSION

The potential of Mungongo *(Ricinodendron rautanenii* schinz*)* as a source of protein in broiler rations was investigated. In the first trial, Soybean-based and Mungongo-based diets were formulated and fed *ad libitum* to broilers for six weeks. The treatments were: SOY (Soybean alone); SOY + A (Soybean + methionine + lysine); MG (Mungongo alone); MG + A (Mungongo + methionine + lysine); MG + A + T (Mungongo + methionine + lysine + tryptophan).

In the second trial the first three treatments in the first trial (SOY, SOY + A and MG) were reformulated while three other treatments; HMG (Heat-treated Mungongo alone), HMG + A (Heat –treated Mungongo + methionine + lysine), and HMG + A + T (Heat-treated Mungongo + methionine + lysine +tryptophan) were also formulated and fed for another six–week period. Mungongo meal was heated to 125°C for 15 minutes in an attempt to deactivate the supposedly present antinutritional factor, ricin. A Completely Randomized Design with 5 treatments in the first trial and 6 treatments in the second trial replicated 3 times was used.

During the first trial, birds on Soybean alone (SOY) were 578.4% heavier ($P \leq 0.0001$) than those on Mungongo alone (MG). Addition of amino acids lysine and methionine to MG increased the live, dressed and carcass weights by 23%, 24% and 24% respectively. Dressed and carcass weights expressed as percentages of liveweights increased by 1% and 0.6% respectively. As for breast weight

expressed as a percentage of carcass weight, this component of carcass increased by 4.1 percentage upon supplementation of Soybean with amino acids lysine and methionine. During the second trial, birds on Soybean alone were 401% heavier ($P \leq 0.0001$) than those that were fed heat-treated Mungongo alone. Addition of amino acids lysine and methionine to SOY increased live, dressed and carcass weights by 26%, 25% and 25% respectively. Addition of amino acids lysine and methionine increased intake and the performance of birds on Soybean diet in terms of live, dressed and carcass weights.

During the first trial, birds on Mungongo alone had the least live, dressed and carcass weights. Addition of amino acids lysine and methionine to MG to form MG + A from MG, increased live, dressed and carcass weights by 502%, 507% and 571% respectively. Breast weight increased by 1712%. However, addition of tryptophan to MG + A reduced live, dressed, carcass and breast weights by 6%, 7%, 5% and 10% respectively. During the second trial, heat treating Mungongo increased live, dressed and carcass weights by 96%, 93% and 105% respectively over untreated Mungongo alone (MG). However, these were not as good as the weights of birds on Soybean-based diets. Addition of amino acids lysine and methionine to heat-treated Mungongo increased the live, dressed and carcass weights by 149%, 203% and 239% respectively. Addition of tryptophan to HMG + A increased live, dressed and carcass weights by 15%, 15% and 16% respectively. The liver and gizzard weights expressed as percentages of carcass weights for birds fed Mungongo alone (MG) were higher than those for birds fed Soybean alone (SOY).

In conclusion Mungongo nut meal can be used as a source of protein in broiler rations provided that amino acids lysine and methionine are supplemented. The live, dressed and carcass weights for birds fed Mungongo supplemented with amino acids lysine and methionine were closer to the acceptable market weights and were not significantly different from those for birds on Soybean alone. Addition of tryptophan only increased the live, dressed and carcass weights when Mungongo was heat treated. However, the performance of birds fed heat treated Mungongo in terms of live, dressed and carcass weights was not as improved as that for birds fed Soybean-based diets, whether amino acids lysine and Methionine were added or tryptophan was added as well. The performance of birds fed untreated Mungongo alone (MG) in terms of live, dressed and carcass weights when amino acids lysine and methionine were supplemented was better than that for birds fed heat-treated Mungongo supplemented with the same amino acids.

6.1 RECOMMENDATIONS

Some suggested recommendations for future researches related to this study include the following:-

(i) Better methods for extracting oil from Mungongo nuts are recommended in future researches.

(ii) Autoclaving method of heat treating Mungongo meal is highly recommended in future researches.

7.0 REFERENCES

Antillon, A. 1976. Pathology of Laying hens fed different levels of Calcium, Phosphorus and Vitamin D3. Ph.D. Thesis, Cornell University.

Austic, R.E. 1983. The availability of amino acids as an attribute of feeds in: Feed Formulation 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.

Agricultural Research Council, 1975. The nutrient requirements of farm livestock No. 1 Poultry. Agricultural Research Council, London.

Botelle, A. 1999. Estimating Manketti Nut Yields in the forest of Western Kavango, Namibia. CRIAA SA – DC, Windhoek.

Behl, C. R; B. Pande and N. Radadia 1986.Nutritive value of castor.Journ.of animal sc.56:473-474.

Bender, A.E. 1983.Hemagglutinins in beans. Food chem. 11:309-320.

Bris, E. and Algeo, J.W.1970.Feedstuffs,Minneap.,42(20):26.

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

Chimbelu, E. G. 1983. The availability, use and management potentials of Mungongo (Ricinodendnon rautanenii, Schinz): A case study of the Southern Shungu Region, Zambia. PhD. Thesis, state University of New York.

Chimbelu , E. G. 1988. Developing Zambian tree resources through community needs and values: 66-75.

Chimbelu, E. G. 1990. Developing Zambian Tree Resources through community needs and values, in utilizing local resources for development, G. Lungwangwa (ed) proceedings of the 9th PWPA Conference, Zambia, 1988.

Cullison, E. A. 1987. Feeds and Feeding. Fourth Edition, Pg. 596

Mutauka (Bsc Thesis 1992) : Ricinodendron rautenenii as protein source in broiler rations.

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

D' Mello, J. P. F. 2000. Nutritional factors and mycotoxins. Farm animal metabolism... pp.383-403.

Endo Y; Tsurugi K.J; Motizuki M. Biol.Chem.1987;262:5908-8130.

Ensminger, M.E and C. G. Olentine, 1978. Feeds and nutrition complete. Clouis, California, Ensminger.

Egan, H.; Kirk, R.; Sawyer, R.1998. Pearson's chemical analysis of foods. Longman. London.

Erkkila, A and H, Siiskonem, 1992: " Forestry in Namibia 1850-1990", Silva Carelica 20:244p.

Fanshawe, E, D. B. 1962. Fifty common trees of Northern Rhodesia. Natural Resources Board and Forestry Department. Government Printers, Lusaka.

Freeman, C. P. 1979. Tryptophan requirement of Broiler chicks. *Broiler Poultry Science* 20 (1): 27 – 37.

F. A. O. 2002. F. A. O Bulletin of 2001 statistics. Volume 2. Rome, Italy. Gomez, K.A., Gomez, A.A., 1984. Statistical Proceedures for Agricultural Research. John Wiley and Sons. New York.

Fondoun, J. M.; Tiki-Manga and J. Kengue 1999: Ricinodenron heudelotti. Newsletter 117:1-11

Graz, F. P. 2002.Description and Ecology of Mungongo in Namibia. Dinteria 27:19-35.

Gunstone, F. D. 2002. "Schinzophyton rautanenii" http://www.polytechnic.ed.na.

Gregory, S and C. Catarina, 2005.Mungongo tree in central Mozambique. FAO links Report 40.

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

Hans, A. S.; Daka, C. B.; Hang'andu, A. K. 1979. *Zambia Journal of Science and Technology*. Volume 4 number 1. National Council for Scientific Research. Kitwe.

Hall,H.T.B.1977. Diseases and Parasites of livestock in the tropics. Longman. Group ltd.157-158.

Jackson , M. R.; LI, S., Day; E. J.; Omar, S. 1989. The effect of different Lysine level feed in constant proportion to different crude protein level on the live performance and carcass characteristics of broiler chicken. *Poultry science*. 68: 186

Julian R.J.1993. Ascites in poultry. Avian pathology.22:419-454.

Kelly, D. F.; Lucke, V.M. , Gaskell, C.J.1982. Notes on pathology for small animal clinicians. John Wright and sons Ltd. England.

Kekeocha, C. C. 1995. Poultry Production handbook. Macmillan Education Ltd. Hong Kong.

Kumar,2003.Feeding values and antinutritive factors of tree legumes by A. Aganga,2003. Pakistan journal of nutrition, 2003.

Lee, R. B. 1973. Mungongo: The Ethnography of a major wild food resource. *Ecology of food and nutrition,* volume 2: 307 -321.

Leslie, E. C. Malden, C. M. 1972. *Poultry Production* 187-188.

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

Leakey, R.B; Mesen and P.N. Mathoka, 1990: Propagation of tropical trees. Forestry Review 69:247.

Liener, I.E.1985. Antinutritional factors in legumes. Marce Derker inc., New York pp.339-382.

Muller, Hans 1988. 'A Trip to Africa a personal report on African fruit and nuts in Rare fruit council of Australia News letter, May 1988.

Mapongmetsen P.M and C. Tchiegang,1996: Mungongo in Cameroon. Agro. fores. 8(2),18-19.

Nielsen, S.S. 1994. Chemical Analysis of Foods. Chapman and Hall, New York, NY.

Olsnes S. and A. Pihl., Biochemistry.1973;12:3121-3126 [Pubmed].

Palmer, E. and N. Pitman, 1972. *Trees of Southern Africa.* Volume 2. Page 1151. Balkema, Cape Town.

Peters, C. R. 1987. Ricinodendron rautanenii (Euphorbia Ceae): Zambezian Wild Food Plant for all season. *Economic Botany* 41:494 – 502.

Peters, C.R. 1987. Ricinodendron rautaneii: Tree Improvement Research Centre. National Council for Scientific Research., Kitwe, Zambia.

Purseglove, J. W. 1987. Tropical Crops: Dicotyledons Longman Group Ltd., London.

Rosa, A. and G. M. Pesti, 2001. Estimation of the tryptophan requirement of chickens for maximum body weight gain and feed efficiency. *Journal of Applied Poultry Research.* 10:135-140. Department of Poultry Science. The University of Georgina, Anthens, Georgia.

Scott, M.L; Mesheim, M.C.; Young, J.R. 1982. Nutrition of the chicken. M.L. Scott and Associates. New York.

Sibbald, I.R.; Slinger, S.J.; Ashton, G.C. 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.

Smith, G.H.; Lewis, D. 1996. Arginine in Poultry Nutrition. 3. Agent and target in amino acids in chicks. *Journal of Nutrition.* 95:547.

Shea, M. M.; J. A. Thomas, P.O. 1990. The effect of dietary tryptophan on aggressive behaviour in developing and mature broiler breeder males. *Poultry Science.* 69: 1994 – 1669.

Smith, N. K and P. W. Waldroup, 1988. Estimation of the tryptophan requirement of male broiler chickens. *Poultry Science* 67 (8):1174 – 117

Springer Berlin and Heidelberg,1949. Journal of the American oil chemists' society, vol. 26.

Storrs, A. E. G. 1995. Know your trees. Some common trees found in Zambia. *Regional Soil Conversation Unit*. 95-96.

Storrs, A. E. G. 1979. Know your trees. Some of the common trees in Zambia. Forestry Department, Ndola

Storrs, A.E. G. 1982. More about trees (A sequel to know your trees). Interesting facts and uses of some common Zambian trees. Forestry Department.

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

Tchiegang, C.; Kapseu and M. Ngassoum, 1997:Ricinodendron heude..Journ. food eng. 32(1):1-10.

Tiki-Manga; T. Kengue and C. Tchiegang, 2000.Chemical composition of Mungongo. African crop Science journal 8, 195-201.

Tane, R. 1997 Etude dela valeur nutritionnelle...Foculte des sciences. Universite de Gent, Belgium.

Taylor, F.W. and B. Kwerepe, 1995. "Domestication of some indigenous fruit trees in Botswana."

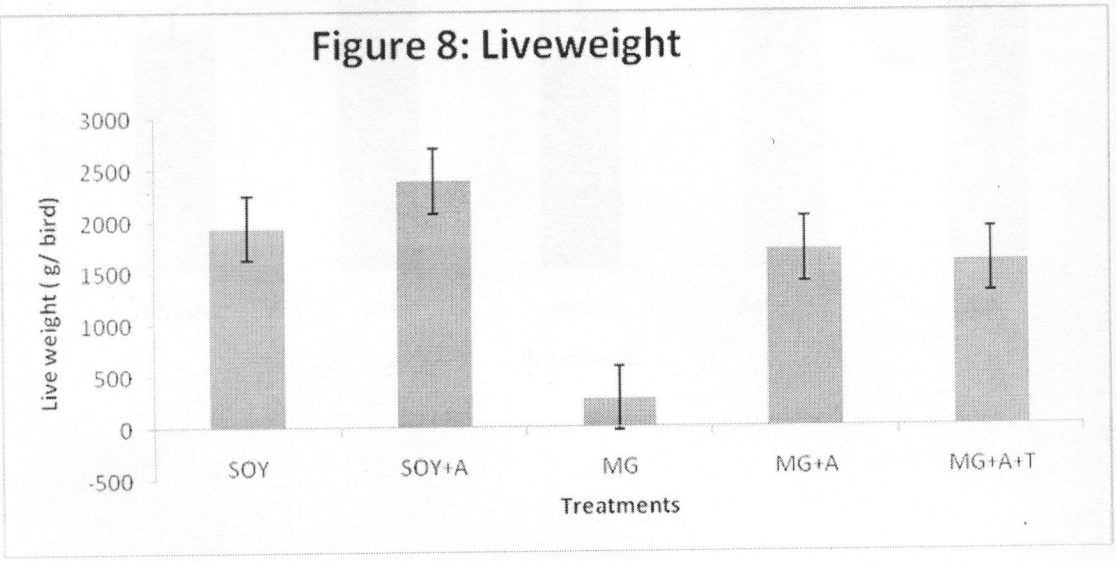
Timberlake, J.R. and G.M. Calvert, 1993. "Preliminary root atlas for Zimbabwe and Zambia" Bulletin of research no.10.Zimbabwe forestry commission, ISBN 07974-1264-6.

Virk, K.S. and U.S. Patent, 1978: Process to improve the quality of grains and seeds...Abstract(17)
pp.387-395.

APPENDICES

APPENDIX 1: CHARTS FOR RESULTS

APPENDIX 1A: CHARTS FOR FIRST TRIAL RESULTS



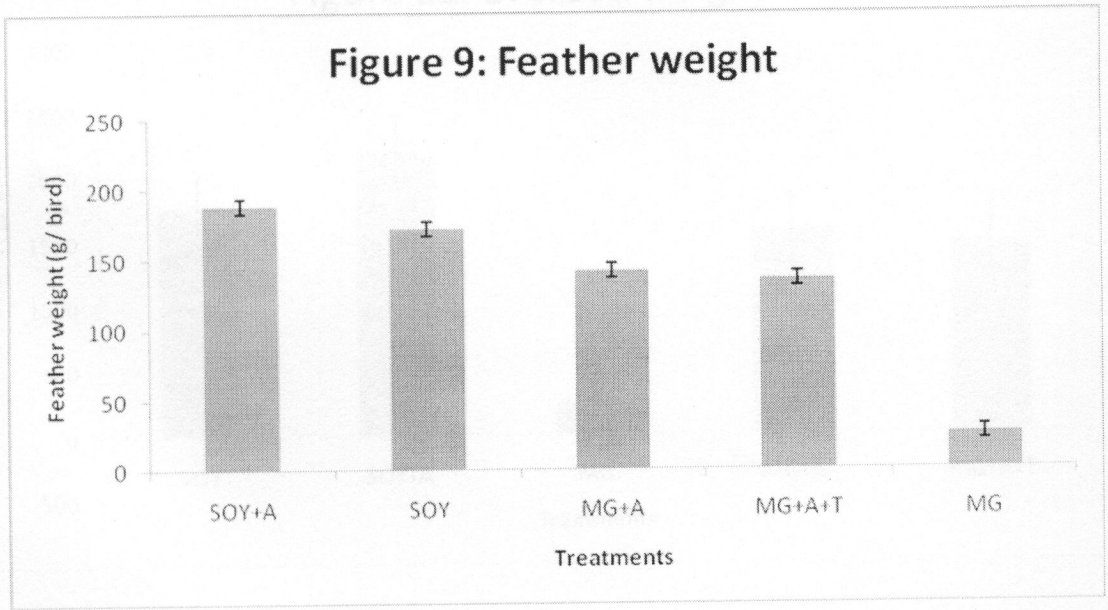


Figure 10: Feather weight as % of liveweight

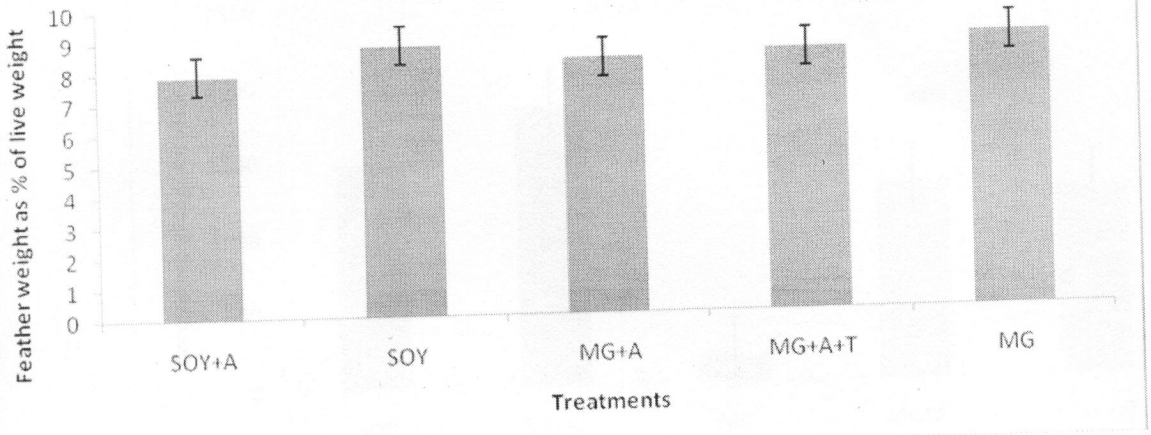


Figure 11: Dressed weight

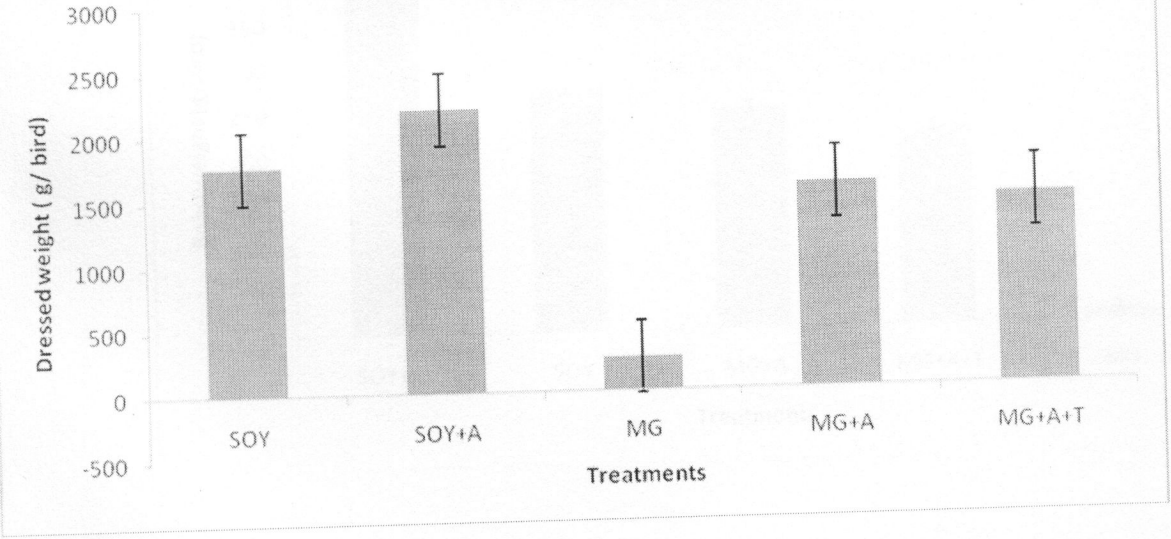


Figure 12: Carcass weight

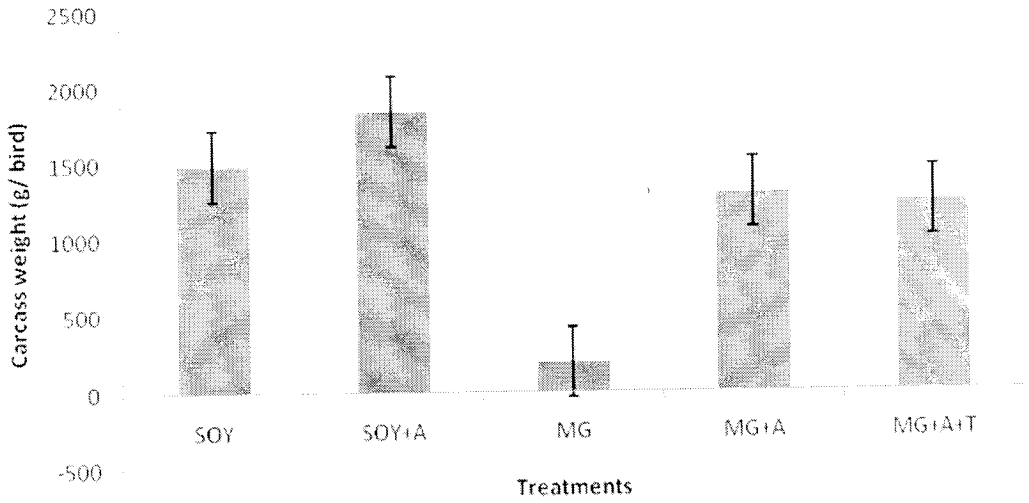


Figure 13: Breast weight

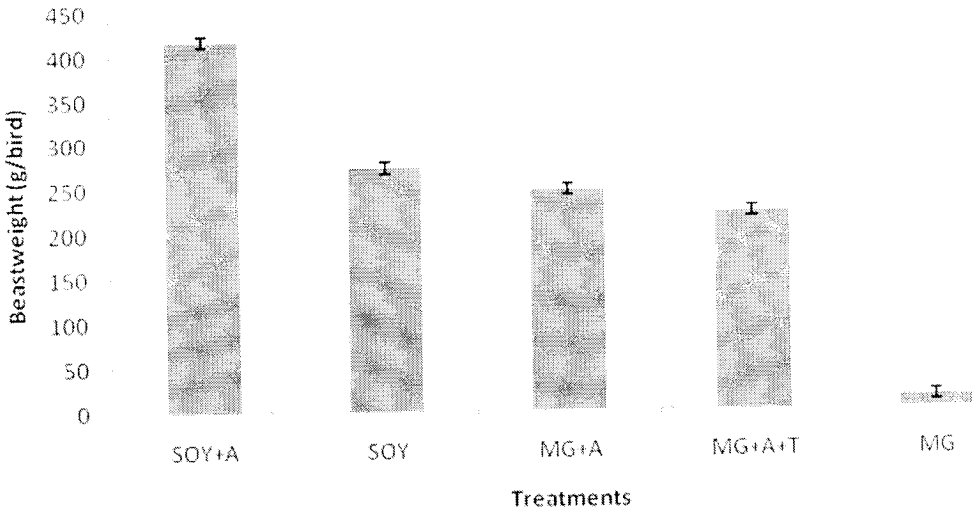
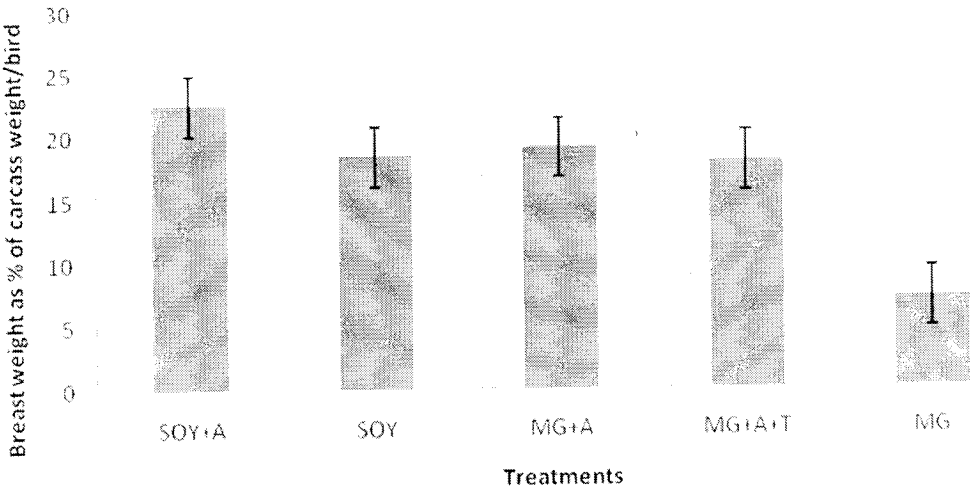


Figure 14: Breast weight as % of carcass weight



APPENDIX 1B: CHARTS FOR SECOND TRIAL RESULTS

Figure 15: Liveweight

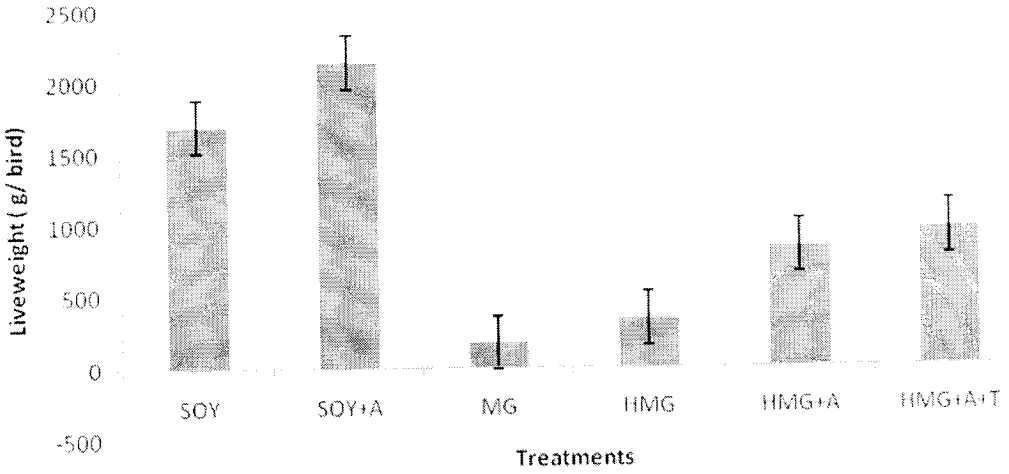


Figure 18: Dressed weight

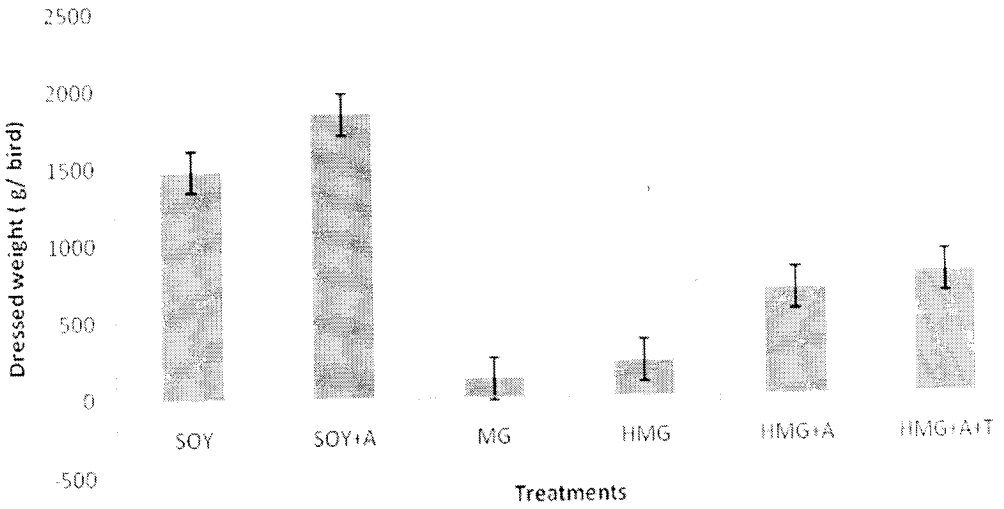


Figure 19: Dressed weight as % of liveweight

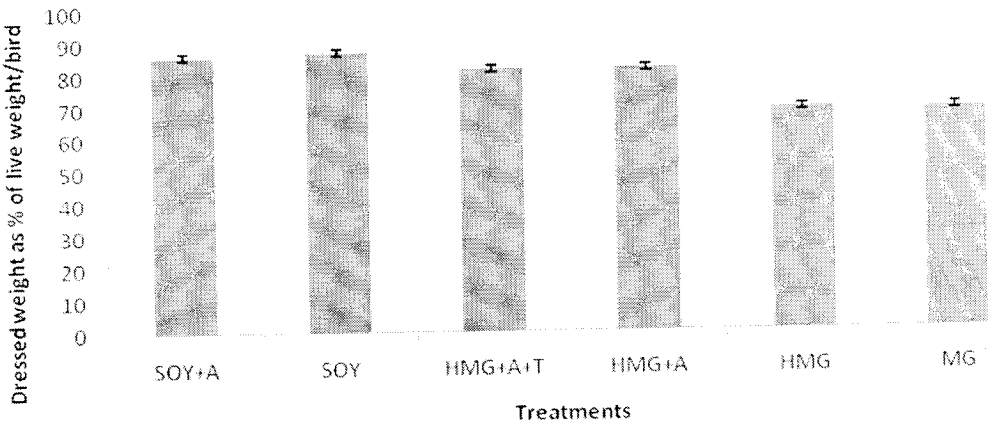


Figure 20: Carcass weight

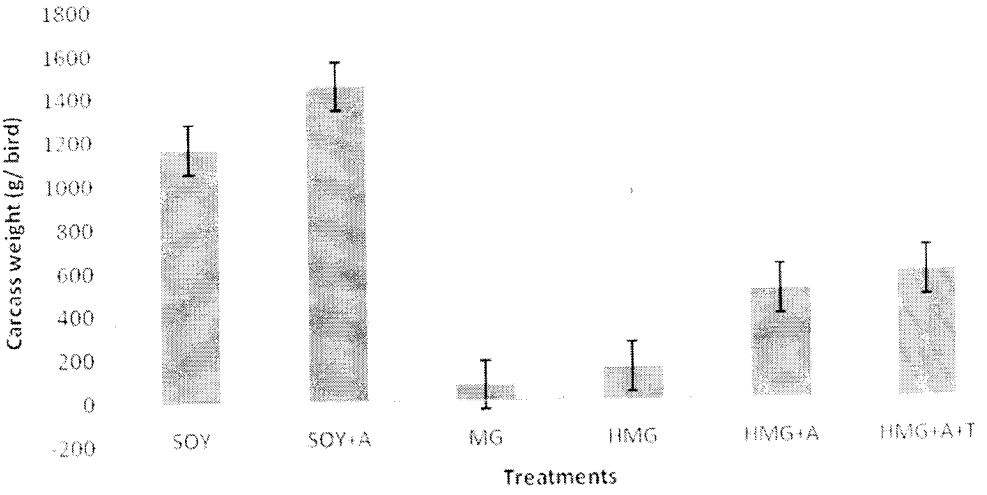


Figure 21: Carcass weight as % of liveweight

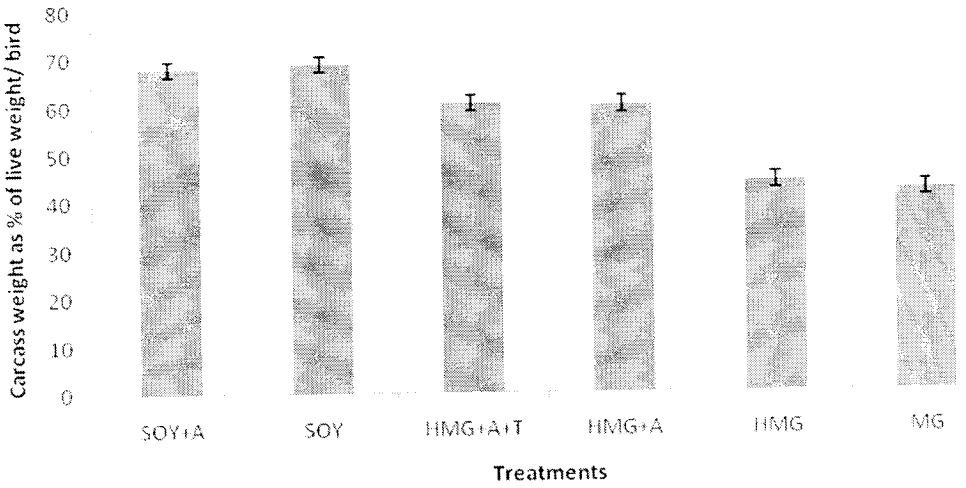


Figure 22: Carcass crude protein percentage

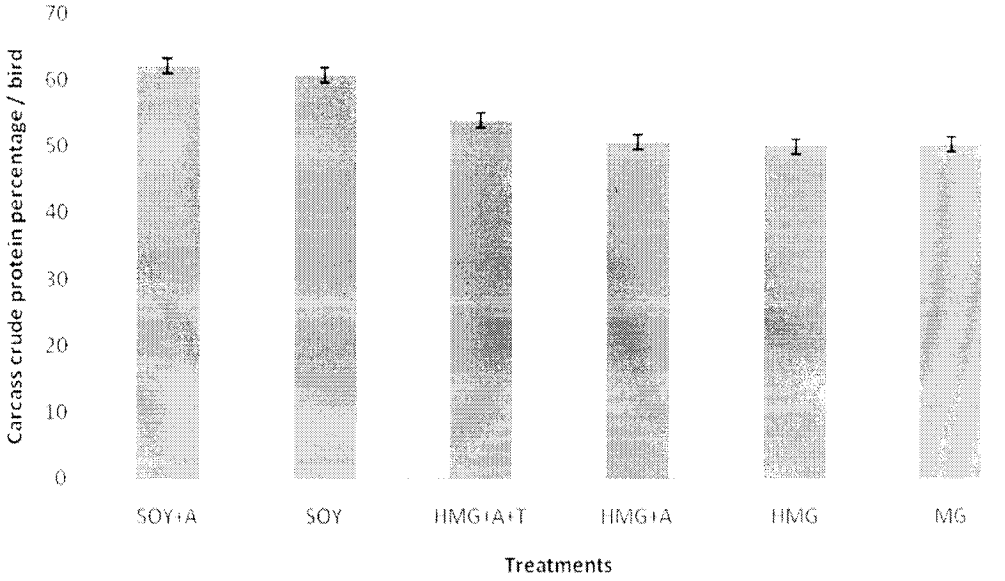


Figure 23: Carcass calcium percentage

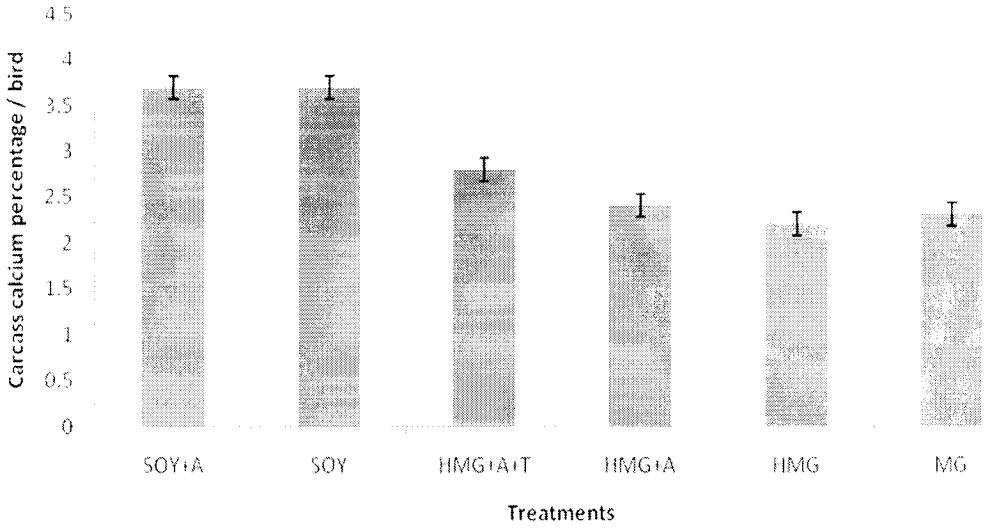


Figure 24: Carcass ash percentage

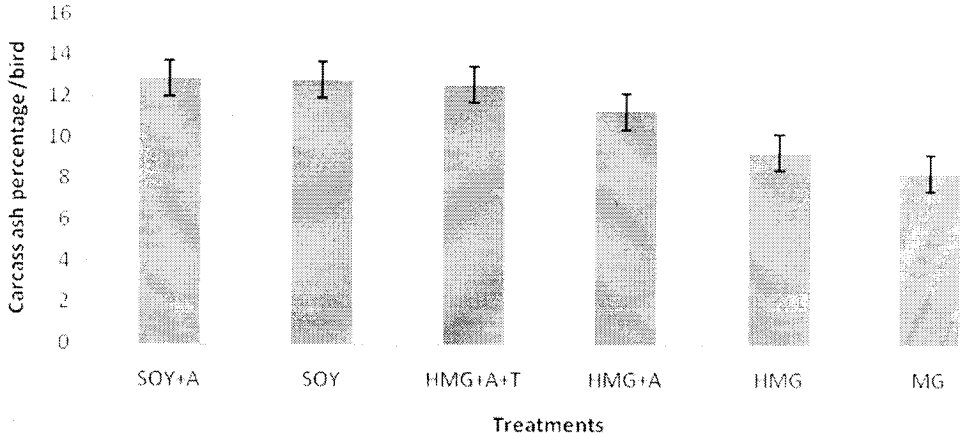
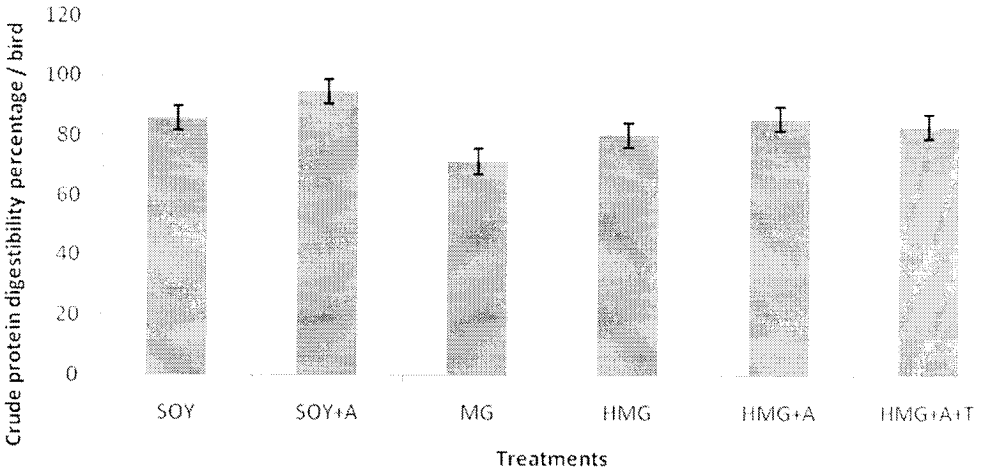


Figure 25: Crude protein digestibility percentage



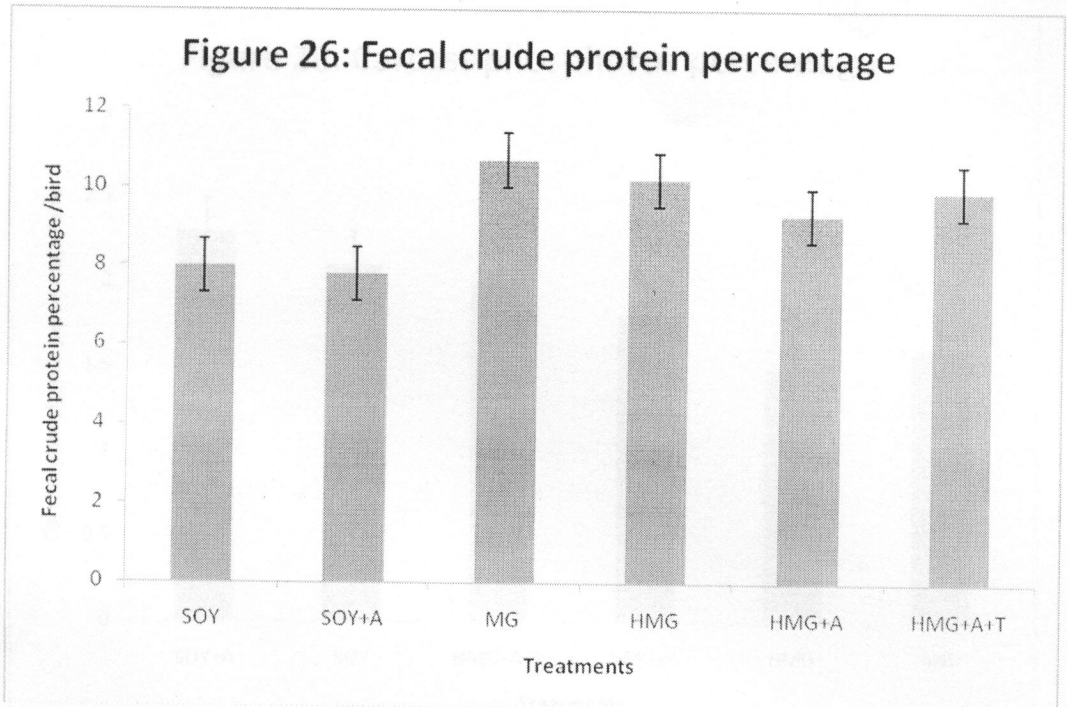


Figure 26: Fecal crude protein percentage
Fecal crude protein percentage /bird
12
10
8
6
4
2
0
SOY
SOY+A
MG
HMG
HMG+A
HMG+A+T
Treatments

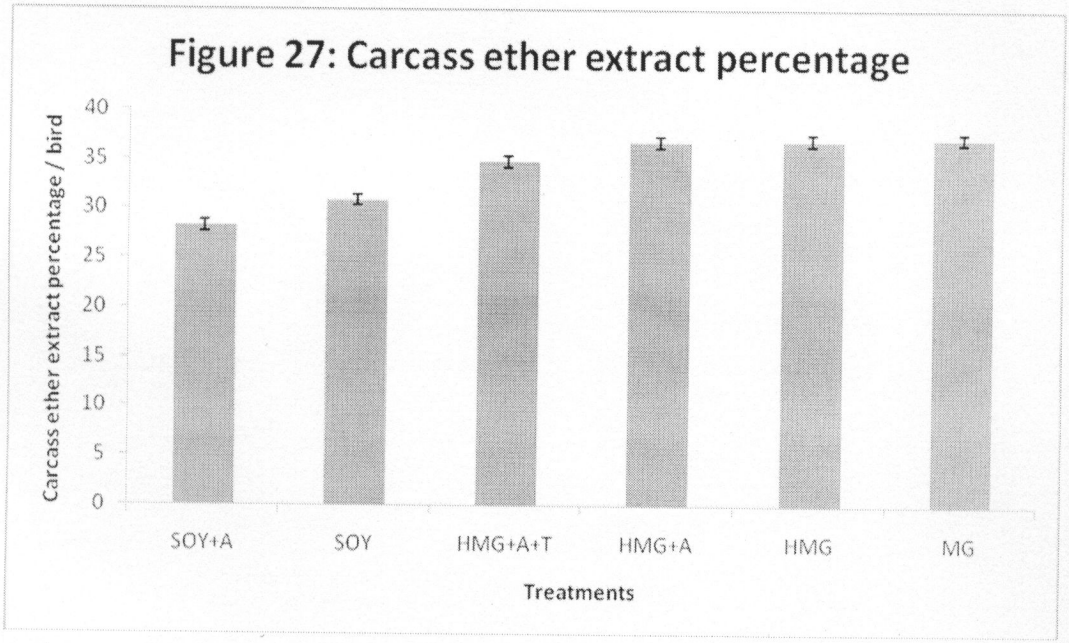
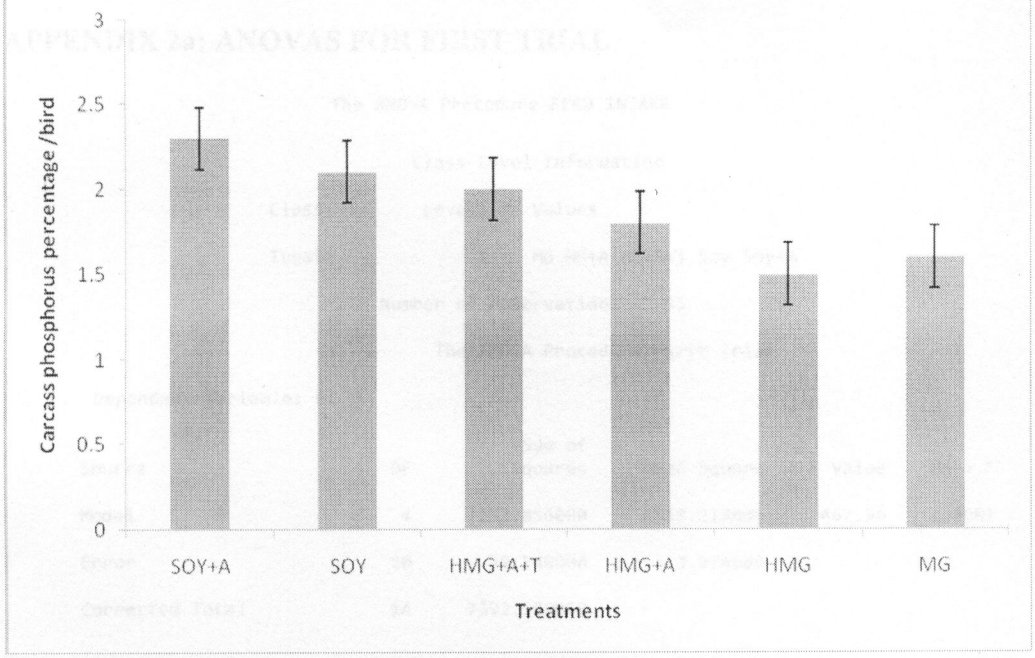


Figure 27: Carcass ether extract percentage
Carcass ether extract percentage / bird
40
35
30
25
20
15
10
5
0
SOY+A
SOY
HMG+A+T
HMG+A
HMG
MG
Treatments

Figure 28: Carcass phosphorus percentage



APPENDIX 2: ANALYSIS OF VARIANCES (ANOVAS) FOR RESULTS

APPENDIX 2a: ANOVAS FOR FIRST TRIAL

The ANOVA Procedure FEED INTAKE

Class Level Information

Class	Levels	Values
Treat1	5	MG MG+A MG+A+T Soy Soy+A

Number of observations 15

The ANOVA Procedure First Trial

i. Dependent Variable: FI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7352.856000	1838.214000	462.56	<.0001
Error	10	39.740000	3.974000		
Corrected Total	14	7392.596000			

R-Square	Coeff Var	Root MSE	FI Mean
0.994624	3.365107	1.993489	59.24000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Treat1	4	7352.856000	1838.214000	462.56	<.0001

The ANOVA Procedure

Duncan's Multiple Range Test for FI FIRST TRIAL

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	10
Error Mean Square	3.974

Number of Means	2	3	4	5
Critical Range	3.627	3.790	3.886	3.947

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Treat1
A	81.300	3	Soy+A
A			
A	79.100	3	Soy
B	59.400	3	MG+A
B			
B	56.700	3	MG+A+T
C	19.700	3	MG

ii. LIVE WEIGHT

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **LVWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 29625.53

Number of Means	2	3	4	5
Critical Range	313.1	327.2	335.5	340.8

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	2388.0	3	SOY+A
B	1942.3	3	SOY
B			
C B	1724.0	3	MG+A
C			
C	1613.0	3	MG+A+T
D	286.3	3	MG

Analysis Variable : **LVWT**

TRT	N Obs	Mean	Std Error
MG	3	286.3333333	34.8440972
MG+A	3	1724.00	125.5401662
MG+A+T	3	1613.00	114.9043080
SOY	3	1942.33	50.8734814
SOY+A	3	2388.00	128.8810821

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

iii.Dependent Variable: DRSDWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	6287840.400	1571960.100	66.70	0.0001
Error	10	235669.333	23566.933		
Corrected Total	14	6523509.733			

R-Square	C.V.	Root MSE	DRSDWT Mean
0.963874	10.53254	153.5153	1457.533

Dependent Variable: **DRSDWT**

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	4	6287840.400	1571960.100	66.70	0.0001

Duncan's Multiple Range Test for variable: DRSDWT

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 23566.93

Number of Means	2	3	4	5
Critical Range	279.3	291.9	299.2	304.0

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	2199.3	3	SOY+A
B	1769.7	3	SOY
B			
C B	1581.7	3	MG+A
C			
C	1476.3	3	MG+A+T
D	260.7	3	MG

Analysis Variable : **DRSDWT**

TRT	N Obs	Mean	Std Error
MG	3	260.6666667	33.2682698
MG+A	3	1581.67	113.3568603
MG+A+T	3	1476.33	108.1578065
SOY	3	1769.67	46.1747887
SOY+A	3	2199.33	107.1981550

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

iv. Dependent Variable: CARCWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	4566553.733	1141638.433	71.05	0.0001
Error	10	160678.000	16067.800		
Corrected Total	14	4727231.733			

R-Square	C.V.	Root MSE	CARCWT Mean
0.966010	10.45118	126.7588	1212.867

Dependent Variable: **CARCWT**

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	4	4566553.733	1141638.433	71.05	0.0001

Duncan's Multiple Range Test for variable: **CARCWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 16067.8

Number of Means	2	3	4	5
Critical Range	230.6	241.0	247.1	251.0

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	1845.0	3	SOY+A
B	1488.0	3	SOY
B			
C B	1299.3	3	MG+A
C			
C	1238.3	3	MG+A+T
D	193.7	3	MG

Analysis Variable : **CARCWT**

TRT	N Obs	Mean	Std Error
MG	3	193.6666667	26.7353283
MG+A	3	1299.33	96.1774979
MG+A+T	3	1238.33	77.9836165
SOY	3	1488.00	37.3229152
SOY+A	3	1845.00	96.6454000

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

v. **Dependent Variable: FTHRWT**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	48916.28400000	12229.07100000	1520.27	0.0001
Error	10	80.44000000	8.04400000		
Corrected Total	14	48996.72400000			

R-Square	C.V.	Root MSE	FTHRWT Mean
0.998358	2.129595	2.8361946	133.18000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	4	48916.28400000	12229.07100000	1520.27	0.0001

Duncan's Multiple Range Test for variable: FTHRWT

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 8.044

Number of Means	2	3	4	5
Critical Range	5.160	5.392	5.529	5.616

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	188.700	3	SOY+A
B	172.600	3	SOY
C	142.300	3	MG+A
D	136.700	3	MG+A+T
E	25.600	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

vi. Dependent Variable: DRSDWT as % of LVWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2.16000000	0.54000000	0.96	0.4681
Error	10	5.60000000	0.56000000		
Corrected Total	14	7.76000000			

R-Square	C.V.	Root MSE	DRSNPC Mean
0.278351	0.817849	0.7483314	91.50000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	4	2.16000000	0.54000000	0.96	0.4681

Duncan's Multiple Range Test for variable: DRSNPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 0.56

Number of Means	2	3	4	5
Critical Range	1.361	1.423	1.459	1.482

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	92.1000	3	SOY+A
A			
A	91.7000	3	MG+A
A			
A	91.5000	3	MG+A+T
A			
A	91.1000	3	SOY
A			
A	91.100	3	MG

Class Level Information

Class	Levels	Values
TREAT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

vii.Dependent Variable: BRSTWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	250588.68000000	62647.17000000	5160.39	0.0001
Error	10	121.40000000	12.14000000		
Corrected Total	14	250710.08000000			

R-Square	C.V.	Root MSE	BRSTWT Mean
0.999516	1.483923	3.4842502	234.80000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	4	250588.68000000	62647.17000000	5160.39	0.0001

Duncan's Multiple Range Test for variable: BRSTWT

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 12.14

Number of Means	2	3	4	5
Critical Range	6.339	6.624	6.792	6.899

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	416.000	3	SOY+A
B	273.300	3	SOY
C	248.300	3	MG+A
D	222.700	3	MG+A+T
E	13.700	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

viii. Dependent Variable: BRST as % of carcwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	406.88400000	101.72100000	60.05	0.0001
Error	10	16.94000000	1.69400000		
Corrected Total	14	423.82400000			

R-Square	C.V.	Root MSE	BRSTPC Mean
0.960031	7.647107	1.3015375	17.02000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	4	406.88400000	101.72100000	60.05	0.0001

Duncan's Multiple Range Test for variable: BRSTPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 1.694

Number of Means	2	3	4	5
Critical Range	2.368	2.474	2.537	2.577

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	22.500	3	SOY+A
B	19.100	3	MG+A
B			
B	18.400	3	SOY
B			
B	18.000	3	MG+A+T
C	7.100	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

ix. Dependent Variable: Fthrwt as % of lvwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.94400000	0.48600000	4.19	0.0301
Error	10	1.16000000	0.11600000		
Corrected Total	14	3.10400000			

R-Square	C.V.	Root MSE	DRSOTPC Mean
0.626289	4.016365	0.3405877	8.48000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	4	1.94400000	0.48600000	4.19	0.0301

Duncan's Multiple Range Test for variable: DRSOTPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 0.116

Number of Means	2	3	4	5
Critical Range	.6196	.6475	.6639	.6744

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	8.9000	3	MG
A			
A	8.8000	3	SOY
A			
B A	8.5000	3	MG+A+T
B A			
B A	8.3000	3	MG+A
B			
B	7.9000	3	SOY+A

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	5	MG MG+A MG+A+T SOY SOY+A

Number of observations in data set = 15

Analysis of Variance Procedure

x. **Dependent Variable: Carcwt as % of lvwt**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	191.84933333	47.96233333	7.75	0.0041
Error	10	61.92000000	6.19200000		
Corrected Total	14	253.76933333			

R-Square	C.V.	Root MSE	CCWTPC Mean
0.755999	3.327888	2.4883729	74.77333333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	4	191.84933333	47.96233333	7.75	0.0041

Duncan's Multiple Range Test for variable: CCWTPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 10 MSE= 6.192

Number of Means	2	3	4	5
Critical Range	4.527	4.731	4.851	4.927

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	77.267	3	SOY+A
A			
A	76.800	3	MG+A+T
A			
A	76.700	3	SOY
A			
A	75.367	3	MG+A
B	67.733	3	MG

APPENDIX 2B: ANOVAS FOR SECOND TRIAL RESULTS

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Treat2	6	HMG HMG+A HMG+A+T MG Soy Soy+A

Number of observations 18

The ANOVA Procedure

xi. Dependent Variable: FEED INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	13575.50500	2715.10100	10376.2	<.0001
Error	12	3.14000	0.26167		
Corrected Total	17	13578.64500			

R-Square	Coeff Var	Root MSE	FI2 Mean
0.999769	1.477709	0.511534	34.61667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Treat2	5	13575.50500	2715.10100	10376.2	<.0001

The ANOVA Procedure

Duncan's Multiple Range Test for FI

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.261667

Number of Means	2	3	4	5	6
Critical Range	0.910	0.953	0.978	0.995	1.007

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Treat2
A	73.3000	3	Soy+A
A	71.0000	3	Soy
B	30.5000	3	HMG+A+T
C	12.9000	3	HMG+A
D	11.5000	3	HMG
E	8.5000	3	MG

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xii. Dependent Variable: LIVE WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	8766403.111	1753280.622	156.69	0.0001
Error	12	134270.000	11189.167		
Corrected Total	17	8900673.111			

R-Square	C.V.	Root MSE	LVWT Mean
0.984915	10.33221	105.7789	1023.778

Dependent Variable: LVWT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	8766403.111	1753280.622	156.69	0.0001

The SAS
Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **LVWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 11189.17

Number of Means	2	3	4	5	6
Critical Range	188.2	197.0	202.3	205.8	208.3

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	2138.33	3	SOY+A
B	1692.33	3	SOY
C	962.33	3	HMG+A+T
C C			
C	839.33	3	HMG+A
D	337.67	3	HMG
D D			
D	172.67	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xiii. Dependent Variable: DRSDWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	6967334.278	1393466.856	241.37	0.0001
Error	12	69276.667	5773.056		
Corrected Total	17	7036610.944			

R-Square	C.V.	Root MSE	DRSDWT Mean
0.990155	8.896450	75.98063	854.0556

Analysis of Variance Procedure

Dependent Variable: DRSDWT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	6967334.278	1393466.856	241.37	0.0001

Duncan's Multiple Range Test for variable:**DRSDWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

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Alpha= 0.05 df= 12 MSE= 5773.056

Number of Means	2	3	4	5	6
Critical Range	135.2	141.5	145.3	147.8	149.6

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	1837.33	3	SOY+A
B	1474.67	3	SOY
C	785.00	3	HMG+A+T
C C			
C	683.67	3	HMG+A
D	225.67	3	HMG
D D			
D	118.00	3	MG

Analysis Variable : **DRSDWT**

TRT	N Obs	Mean	Std Error
MG	3	118.0000000	6.8068593
HMG	3	225.6666667	33.1980588
HMG+A	3	683.6666667	59.7559853
HMG+A+T	3	785.0000000	65.4930022
SOY	3	1474.67	32.0953441
SOY+A	3	1837.33	38.8258219

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xiv.Dependent Variable: CARCWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	4569543.611	913908.722	226.47	0.0001
Error	12	48426.000	4035.500		
Corrected Total	17	4617969.611			

R-Square	C.V.	Root MSE	CARCSWT Mean
0.989514	9.694451	63.52559	655.2778

Analysis of Variance Procedure

Dependent Variable: CARCWT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	4569543.611	913908.722	226.47	0.0001

The SAS System
Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **CARCWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 4035.5

Number of Means	2	3	4	5	6
Critical Range	113.0	118.3	121.5	123.6	125.1

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	1454.00	3	SOY+A
B	1167.00	3	SOY
C	583.67	3	HMG+A+T
C C			
C	505.33	3	HMG+A
D	149.00	3	HMG
D D			
D	72.67	3	MG

Analysis Variable: **CARCSWT**

TRT	N Obs	Mean	Std Error
MG	3	72.6666667	3.4801022
HMG	3	149.0000000	20.5020324
HMG+A	3	505.3333333	41.4902934
HMG+A+T	3	583.6666667	45.9939610
SOY	3	1167.00	31.2623309
SOY+A	3	1454.00	53.1444572

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
TREAT	6	HMG HMG+A HMG+A+T MG SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xv. Dependent Variable: FTHRWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	109034.88000000	21806.97600000	53623.71	0.0001
Error	12	4.88000000	0.40666667		
Corrected Total	17	109039.76000000			

R-Square	C.V.	Root MSE	FTHRWT Mean
0.999955	0.375783	0.6377042	169.70000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	109034.88000000	21806.97600000	53623.71	0.0001

Duncan's Multiple Range Test for variable: FTHRWT

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.406667

Number of Means	2	3	4	5	6
Critical Range	1.134	1.187	1.220	1.241	1.256

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	301.0000	3	SOY+A
B	217.6000	3	SOY
C	177.3000	3	HMG+A+T
D	155.6000	3	HMG+A
E	112.0000	3	HMG
F	54.7000	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	HMG HMG+A HMG+A+T MG SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xvi.Dependent Variable: Drdsdwt as % of lvwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1033.96000000	206.79200000	623.49	0.0001
Error	12	3.98000000	0.33166667		
Corrected Total	17	1037.94000000			

R-Square	C.V.	Root MSE	DRSNPC Mean
0.996165	0.730226	0.5759050	78.86666667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	1033.96000000	206.79200000	623.49	0.0001

Duncan's Multiple Range Test for variable: DRSNPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.331667

Number of Means	2	3	4	5	6
Critical Range	1.025	1.072	1.101	1.121	1.134

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	87.1000	3	SOY
B	85.9000	3	SOY+A
C	81.6000	3	HMG+A+T
C C			
C	81.5000	3	HMG+A
D	68.8000	3	HMG
D D			
D	68.3000	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	HMG HMG+A HMG+A+T MG SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xvii. Dependent Variable: Livrwt as % ofcarcwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	45.34944444	9.06988889	30.69	0.0001
Error	12	3.54666667	0.29555556		
Corrected Total	17	48.89611111			

R-Square	C.V.	Root MSE	LIVRPC Mean
0.927465	8.531564	0.5436502	6.37222222

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	45.34944444	9.06988889	30.69	0.0001

Duncan's Multiple Range Test for variable: LIVRPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.295556

Number of Means	2	3	4	5	6
Critical Range	0.967	1.012	1.040	1.058	1.070

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	8.7000	3	MG
A			
A	8.2333	3	HMG
B	6.1000	3	HMG+A
B			
B	5.9000	3	HMG+A+T
C	4.7000	3	SOY
C			
C	4.6000	3	SOY+A

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	HMG HMG+A HMG+A+T MG SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xviii. Dependent Variable: Gzdwt as % of carcwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	473.38000000	94.67600000	312.12	0.0001
Error	12	3.64000000	0.30333333		
Corrected Total	17	477.02000000			

R-Square	C.V.	Root MSE	GZDPC Mean
0.992369	5.115391	0.5507570	10.76666667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	473.38000000	94.67600000	312.12	0.0001

Duncan's Multiple Range Test for variable: GZDPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.303333

Number of Means	2	3	4	5	6
Critical Range	0.980	1.026	1.053	1.072	1.084

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	20.2000	3	MG
B	14.6000	3	HMG
C	9.4000	3	HMG+A
C			
C	8.6000	3	HMG+A+T
D	6.2000	3	SOY+A
D			
D	5.6000	3	SOY

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	HMG HMG+A HMG+A+T MG SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xix.Dependent Variable: Fthrwt as % of lvwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1164.76000000	232.95200000	446.55	0.0001
Error	12	6.26000000	0.52166667		
Corrected Total	17	1171.02000000			

R-Square	C.V.	Root MSE	DRSNOTPC Mean
0.994654	3.364588	0.7222649	21.46666667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	1164.76000000	232.95200000	446.55	0.0001

Duncan's Multiple Range Test for variable: DRSNOTPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.521667

Number of Means	2	3	4	5	6
Critical Range	1.285	1.345	1.381	1.405	1.422

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	33.2000	3	HMG
B	31.7000	3	MG
C	18.5000	3	HMG+A
C			
C	18.4000	3	HMG+A+T
D	14.1000	3	SOY+A
D			
D	12.9000	3	SOY

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	HMG HMG+A HMG+A+T MG SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xx. Dependent Variable: Carcwt as % of lvwt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2014.67611111	402.93522222	472.81	0.0001
Error	12	10.22666667	0.85222222		
Corrected Total	17	2024.90277778			

R-Square	C.V.	Root MSE	CCWTPC Mean
0.994950	1.610005	0.9231588	57.33888889

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	2014.67611111	402.93522222	472.81	0.0001

Duncan's Multiple Range Test for variable: CCWTPC

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.852222

Number of Means	2	3	4	5	6
Critical Range	1.642	1.719	1.765	1.796	1.818

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	68.9667	3	SOY
A			
A	67.9667	3	SOY+A
B	60.6000	3	HMG+A+T
B			
B	60.2000	3	HMG+A
C	44.1333	3	HMG
D	42.1667	3	MG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxi.Dependent Variable: LIVRWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	8174.500000	1634.900000	59.45	0.0001
Error	12	330.000000	27.500000		
Corrected Total	17	8504.500000			

R-Square	C.V.	Root MSE	LIVRWT Mean
0.961197	15.20013	5.244044	34.50000

Dependent Variable: LIVRWT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	8174.500000	1634.900000	59.45	0.0001

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **LIVRWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 27.5

Number of Means	2	3	4	5	6
Critical Range	9.33	9.76	10.03	10.20	10.32

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	66.667	3	SOY+A
B	55.333	3	SOY
C	34.667	3	HMG+A+T
C C			
C	30.667	3	HMG+A
D	13.333	3	HMG
D D			
D	6.333	3	MG

Analysis Variable: **LIVRWT**

TRT	N Obs	Mean	Std Error
MG	3	6.3333333	0.6666667
PMG	3	13.3333333	2.4037009
PMG+A	3	30.6666667	4.4095855
PMG+A+T	3	34.6666667	1.4529663
SOY	3	55.3333333	2.3333333
SOY+A	3	66.6666667	4.6666667

Analysis of Variance Procedu
Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxii. Dependent Variable: GZDWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11820.94444	2364.18889	23.85	0.0001
Error	12	1189.33333	99.11111		
Corrected Total	17	13010.27778			

R-Square	C.V.	Root MSE	GZDWT Mean
0.908585	20.57385	9.955456	48.38889

Dependent Variable: GZDWT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	11820.94444	2364.18889	23.85	0.0001

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **GZDWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 99.11111

Number of Means	2	3	4	5	6
Critical Range	17.71	18.54	19.04	19.37	19.60

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	90.667	3	SOY+A
B	65.667	3	SOY
B			
B	50.000	3	HMG+A+T
B			
B	47.667	3	HMG+A
C	21.667	3	HMG
C			
C	14.667	3	MG

Analysis Variable : **GZDWT**

TRT	N Obs	Mean	Std Error
MG	3	14.6666667	1.4529663
PMG	3	21.6666667	3.1797973
PMG+A	3	47.6666667	5.0442487
PMG+A+T	3	50.0000000	6.0277138
SOY	3	65.6666667	7.5351030
SOY+A	3	90.6666667	8.2124567

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxiii. Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	455.7482944	91.1496589	225.63	0.0001
Error	12	4.8477333	0.4039778		
Corrected Total	17	460.5960278			

R-Square	C.V.	Root MSE	CP Mean
0.989475	1.163793	0.635592	54.61389

Analysis of Variance Procedure
Dependent Variable: CP

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	455.7482944	91.1496589	225.63	0.0001

Duncan's Multiple Range Test for variable: CP

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.403978

Number of Means	2	3	4	5	6
Critical Range	1.131	1.184	1.216	1.237	1.251

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	62.1500	3	SOY+A
B	60.7667	3	SOY
C	53.9600	3	HMG+A+T
D	50.6267	3	HMG+A
D D	50.1600	3	MG
D D	50.0200	3	HMG

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxiv. Dependent Variable: EE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	207.0007167	41.4001433	401.25	0.0001
Error	12	1.2381333	0.1031778		
Corrected Total	17	208.2388500			

R-Square	C.V.	Root MSE	EE Mean
0.994054	0.940457	0.321213	34.15500

Dependent Variable: EE

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	207.0007167	41.4001433	401.25	0.0001

Duncan's Multiple Range Test for variable: EE

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.103178

Number of Means	2	3	4	5	6
Critical Range	.5714	.5981	.6143	.6250	.6324

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	37.0833	3	HMG
A			
A	37.0233	3	MG
A			
A	36.8067	3	HMG+A
B	34.8000	3	HMG+A+T
C	30.9133	3	SOY
D	28.3033	3	SOY+A

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxv. Dependent Variable: Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	7.18929444	1.43785889	282.86	0.0001
Error	12	0.06100000	0.00508333		
Corrected Total	17	7.25029444			

R-Square	C.V.	Root MSE	CA Mean
0.991587	2.492435	0.071297	2.860556

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Dependent Variable: **Ca**

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	7.18929444	1.43785889	282.86	0.0001

Duncan's Multiple Range Test for variable: Ca

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.005083

Number of Means	2	3	4	5	6
Critical Range	.1268	.1328	.1364	.1387	.1404

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	3.71333	3	SOY+A
A			
A	3.71000	3	SOY
B	2.83667	3	HMG+A+T
C	2.35333	3	HMG+A
C			
C	2.32000	3	MG
C			
C	2.23000	3	HMG

Analysis variable:**Ca**

TREAT	N Obs	Mean	Std Error
MG	3	2.3200000	0.0057735
HMG	3	2.2300000	0.0360555
HMG+A	3	2.3533333	0.0317980
HMG+A+T	3	2.8366667	0.0674125
SOY	3	3.7100000	0.0404145
SOY+A	3	3.7133333	0.0405518

Analysis Variable : EE

TREAT	N Obs	Mean	Std Error
MG	3	37.0233333	0.0338296
HMG	3	37.0833333	0.0145297
HMG+A	3	36.8066667	0.1560271
HMG+A+T	3	34.8000000	0.0115470
SOY	3	30.9133333	0.1377599
SOY+A	3	28.3033333	0.4019259

Analysis Variable: CP

TREAT	N Obs	Mean	Std Error
MG	3	50.1600000	0.0888819
HMG	3	50.0200000	0.0416333
HMG+A	3	50.6266667	0.4005136
HMG+A+T	3	53.9600000	0.1026320
SOY	3	60.7666667	0.3851551
SOY+A	3	62.1500000	0.6921223

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxvi. Dependent Variable: P

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1.61416111	0.32283222	30.71	0.0001
Error	12	0.12613333	0.01051111		
Corrected Total	17	1.74029444			

R-Square	C.V.	Root MSE	P Mean
0.927522	5.394407	0.102524	1.900556

Dependent Variable: P

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	1.61416111	0.32283222	30.71	0.0001

Duncan's Multiple Range Test for variable: P

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.010511

Number of Means	2	3	4	5	6
Critical Range	.1824	.1909	.1961	.1995	.2019

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	2.33667	3	SOY+A
B	2.14333	3	SOY
B			
B	2.06333	3	HMG+A+T
C	1.75000	3	HMG+A
C			
D C	1.57667	3	MG
D			
D	1.53333	3	HMG

Analysis Variable : P

TREAT	N Obs	Mean	Std Error
MG	3	1.5766667	0.0284800
HMG	3	1.5333333	0.0352767
HMG+A	3	1.7500000	0.0264575
HMG+A+T	3	2.0633333	0.1020349
SOY	3	2.1433333	0.0617342
SOY+A	3	2.3366667	0.0635959

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TREAT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Analysis of Variance Procedure

xxvii. Dependent Variable: ASH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	58.00506667	11.60101333	48.06	0.0001
Error	12	2.89633333	0.24136111		
Corrected Total	17	60.90140000			

R-Square	C.V.	Root MSE	ASH Mean
0.952442	4.391703	0.491285	11.18667

Dependent Variable: ASH

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TREAT	5	58.00506667	11.60101333	48.06	0.0001

Duncan's Multiple Range Test for variable: **ASH**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.241361

Number of Means	2	3	4	5	6
Critical Range	.8740	.9148	.9396	.9559	.9673

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TREAT
A	12.8967	3	HMG
A			
A	12.8167	3	MG
A			
A	12.5667	3	HMG+A
B	11.2400	3	HMG+A+T
C	9.2767	3	SOY+A
D	8.3233	3	SOY

Analysis Variable : **ASH**

TREAT	N Obs	Mean	Std Error
MG	3	12.8166667	0.0554777
HMG	3	12.8966667	0.0284800
HMG+A	3	12.5666667	0.2445631
HMG+A+T	3	11.2400000	0.0916515
SOY	3	8.3233333	0.2511529
SOY+A	3	9.2766667	0.5895290

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxviii. Dependent Variable: FECWT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	508709.7778	101741.9556	50.23	0.0001
Error	12	24305.3333	2025.4444		
Corrected Total	17	533015.1111			

R-Square	C.V.	Root MSE	FECWT Mean
0.954400	21.40827	45.00494	210.2222

Analysis of Variance Procedure

Dependent Variable: FECWT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	508709.7778	101741.9556	50.23	0.0001

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **FECWT**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 2025.444

Number of Means	2	3	4	5	6
Critical Range	80.06	83.80	86.07	87.57	88.61

Means with the same letter are not signif .fferent.

Duncan Grouping		Mean	N	TRT
	A	548.67	3	SOY+A
	B	263.00	3	SOY
	B			
C	B	185.67	3	HMG+A
C				
C		154.00	3	HMG+A+T
	D	67.00	3	HMG
	D			
	D	43.00	3	MG

Analysis Variable: **FECWT**

TRT	N Obs	Mean	Std Error
MG	3	43.0000000	23.5017730
PMG	3	67.0000000	5.5075705
PMG+A	3	185.6666667	28.5034111
PMG+A+T	3	154.0000000	32.5166624
SOY	3	263.0000000	28.7460142
SOY+A	3	548.6666667	27.7868874

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxix. Dependent Variable: DGSCP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	881.0997778	176.2199556	32.65	0.0001
Error	12	64.7682000	5.3973500		
Corrected Total	17	945.8679778			

R-Square	C.V.	Root MSE	DGSCP Mean
0.931525	2.775025	2.323220	83.71889

Analysis of Variance Procedure

Dependent Variable: DGSCP

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	881.0997778	176.2199556	32.65	0.0001

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **DGSCP**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 5.39735

Number of Means	2	3	4	5	6
Critical Range	4.133	4.326	4.443	4.520	4.574

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	94.983	3	MG
B	86.007	3	HMG+A
B			
B	85.850	3	HMG
B			
C B	83.440	3	HMG+A+T
C			
C	80.393	3	SOY
D	71.640	3	SOY+A

Analysis Variable : **DGSCP**

TRT	N Obs	Mean	Std Error
MG	3	94.9833333	0.7858400
HMG	3	85.8500000	0.8151278
HMG+A	3	86.0066667	2.8843389
HMG+A+T	3	83.4400000	0.2040425
SOY	3	80.3933333	0.8205147
SOY+A	3	71.6400000	0.6916888

Analysis of Variance Procedure
Class Level In

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxx.Dependent Variable: FECCP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	21.66784444	4.33356889	29.09	0.0001
Error	12	1.78786667	0.14898889		
Corrected Total	17	23.45571111			

R-Square	C.V.	Root MSE	FECCP Mean
0.923777	4.136108	0.385991	9.332222

Analysis of Variance Procedure

Dependent Variable: **FECCP**

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	21.66784444	4.33356889	29.09	0.0001

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **FECCP**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 0.148989

Number of Means	2	3	4	5	6
Critical Range	.6867	.7188	.7382	.7510	.7600

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	10.7167	3	MG
A			
B A	10.2367	3	HMG
B			
B C	9.9500	3	HMG+A+T
C			
C	9.2800	3	HMG+A
D	8.0267	3	SOY
D			
D	7.7833	3	SOY+A

Analysis Variable : **FECCP**

TRT	N Obs	Mean	Std Error
MG	3	10.7166667	0.0233333
HMG	3	10.2366667	0.0635959
HMG+A	3	9.2800000	0.0901850
HMG+A+T	3	9.9500000	0.5325724
SOY	3	8.0266667	0.0328295
SOY+A	3	7.7833333	0.0233333

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
TRT	6	MG HMG HMG+A HMG+A+T SOY SOY+A

Number of observations in data set = 18

Analysis of Variance Procedure

xxxi. Dependent Variable: DGSCF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	518.9567167	103.7913433	8.53	0.0012
Error	12	145.9999333	12.1666611		
Corrected Total	17	664.9566500			

R-Square	C.V.	Root MSE	DGSCF Mean
0.780437	4.192985	3.488074	83.18833

Analysis of Variance Procedure

Dependent Variable: DGSCF

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	5	518.9567167	103.7913433	8.53	0.0012

Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: **DGSCF**

NOTE: This test controls the type I comparisonwise error rate, not the experimentwise error rate

Alpha= 0.05 df= 12 MSE= 12.16666

Number of Means	2	3	4	5	6
Critical Range	6.205	6.495	6.671	6.787	6.868

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TRT
A	93.097	3	MG
B	85.263	3	HMG
B			
B	84.120	3	SOY
B			
C B	80.763	3	HMG+A
C B			
C B	80.033	3	SOY+A
C			
C	75.853	3	HMG+A+T

Analysis Variable : **DGSCF**

TRT	N Obs	Mean	Std Error
MG	3	93.0966667	1.1445863
HMG	3	85.2633333	2.7074978
HMG+A	3	80.7633333	1.8840058
HMG+A+T	3	75.8533333	3.2870318
SOY	3	84.1200000	0.9473296
SOY+A	3	80.0333333	0.6642372

Appendix 3: Nutrient content of ingredients used in feed formulations in percentage

Ingredient	Salt	TRP	DM	CP	CF	EE	Ca*	P[b]	B/Prex	LYS	MET
Maize Meal	-	0.04	89.51	8.9	8.23	3.13	0.02	0.29	-	0.29	0.27
Soya Meal	-	0.55	88.54	43.92	6.4	1.27	0.30	0.66	-	3.31	0.92
Mungongo Meal	-	0.00	92.50	38.80	8.85	14.85	0.46	0.73	-	1.05	0.81
DCP	-	-	-	-	-	-	23.35	18.21	-	-	-
Limestone	-	-	-	-	-	-	38	-	-	-	-
Lysine	-	-	-	-	-	-	-	-	-	0.99	-
Methionine	-	-	-	-	-	-	-	-	-	-	0.99
Salt	0.99	-	-	-	-	-	-	-	-	-	-
B/Prex	-	-	-	-	-	-	-	-	0.99	-	-
Tryptophan	-	0.99	-	-	-	-	-	-	-	-	-

N.B: As determined by chemical analysis except for Amino acids

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

b P in plants is $\frac{1}{3}$ available to poultry (Ensminger et al., 1990)

Appendix 4 (i): Proximate analysis of diets (Starter)-Second trial

Feed	CP%	MOIST%	DM%	EE%	ASH%	CF%	Ca%	P%
SOY+A	22.25	13.84	86.16	3.63	8.14	2.44	0.94	0.48
SOY	21.63	16.27	83.75	4.22	8.45	3.53	0.97	0.49
HMG+A	23.01	8.95	91.05	14.48	7.78	4.11	0.98	0.45
HMG+A+T	22.35	9.66	90.34	16.59	7.83	6.84	0.98	0.46
MG	21.72	9.89	91.11	15.36	6.72	7.03	0.94	0.48
HMG	21.56	9.49	90.51	15.38	6.76	7.31	0.98	0.51

Appendix 4 (ii): Proximate analysis of diets (Finisher)-Second trial

Feed	CP%	MOIST%	DM%	EE%	ASH%	CF%	Ca%	P%
SOY+A	18.25	11.03	88.97	5.87	5.19	3.78	0.84	0.45
SOY	18.3	11.02	89.98	4.49	5.13	2.63	0.8	0.4
HMG+A	18.98	9.41	90.59	16.99	6.11	6.92	0.92	0.43
HMG+A+T	19.01	8.85	91.15	15.26	5.42	4.54	0.88	0.41
MG	18.28	9.36	90.64	15.46	5.52	7.09	0.82	0.41
HMG	17.56	8.98	91.02	16.92	5.56	7.86	0.82	0.42