EVALUATION OF THE COST-EFFECTIVENESS OF DRIED BAKERY PRODUCTS AS FEED FOR SMALL-SCALE BROILER PRODUCTION

by

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DEDICATION

To all my family members, especially my parents,

Mr Faustin Kabengele Muenje and Mrs Alphonsine Nyamabo Muenje

for years of love, patience, encouragement and support.

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SUMMARY

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Promoter: **Professor C M E McCrindle**

Department: **Paraclinical Sciences**

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The high prices of available supplies of cereals like maize, barley, and oats has aroused considerable interest in stepping up the use of unconventional energy and protein feed sources to reduce the costs (costs of feed and total production costs) and improve the efficiency of small-scale poultry units. Dried Bakery products (DBP), is one of these unconventional ingredients produced in large quantities in South Africa, which is available for animal feeding.

The aim of this study was to determine the cost effectiveness of the use of DBP with commercial rations, using the choice feeding method, without compromising performance of broilers produced in small-scale commercial poultry enterprise.

A total of five hundred and seventy day-old-male broiler chicks (Ross), were assigned to three feeding treatments of 190 birds each over a period of 42 days. All the birds, in all three groups, were given a complete diet (starter mash) the first seven days. Treatment A (TA) was fed as a two stage (starter and grower ration) complete diet and acted as a control.

Besides DBP acting as a substitute energy source, salt (NaCl) concentration (being a limiting factor in broiler rations) was also considered as a target for selection. Treatment B (TB) was given a starter ration up to day seven, thereafter, receiving simultaneous access to a complete diet containing a normal salt percentage and DBP. Treatment C (TC) was given starter ration to day seven, thereafter receiving simultaneous access to a complete diet containing a low salt percentage and DBP.

The performance of birds was measured in terms of feed intake, weight gains, feed conversion rate and mortality. In addition, an economic evaluation (cost analysis, net profit, total physical product (TPP), average physical product (APP), marginal physical product (MPP) calculations and gross margin analysis) was done. DBP was also analysed for its nutrient composition, as well as tested for aflatoxin.

The use of DBP in groups TB and TC resulted in a reduction of the feed costs by nearly a third and consequently had a positive impact on the total cost of production, net profit and gross margin analysis per live bird and per kg of live birds in contrast to the control group (TA).

The TPP, APP and MPP calculations revealed that the use of DBP was beneficial during the entire production period since the value of the marginal product remained higher than the cost of DBP.

This study has also confirmed that chickens are able to self-select their diets when raised under choice situations. This is shown by the performance of birds in terms of body weight, feed intake feed conversion, mortality and necropsy results. Groups TB and TC had similar body weights, feed intake, mortality % and feed conversion. The feed conversion was slightly (but not significantly), higher for TB and TC than for TA. This suggests that the conversion of DBP into kg live weight of chickens in groups TB and TC, was at least as efficient as the control diet (TA).

It can be concluded from the results, that DBP can be safely used as a viable alternative energy feed source in a small-scale broiler production system. The higher salt content of DBP did not play a significant role in choice of ration by the birds (TB and TC were not significantly different).

The use of the choice feeding method was successful and showed that it was a practical alternative to computer formulation of rations, as it allows the birds to ingest a percentage of DBP in the ration to meet their growth requirements. The use of DBP and starter ration on a choice feeding system (TB and TC) rather than starter and grower ration in a two-stage system (TA) resulted in increased productivity and profitability.

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CHAPTER I

INTRODUCTION

1.1 Motivation

In the face of population growth and urbanisation, increasing the supply of animal products is a major factor contributing to food security and quality. Poultry rearing is one of the activities that can directly address this important issue.

World poultry meat (chicken, turkey and duck) consumption is of significant economic importance in more than 50 countries. In 1997, worldwide demand for poultry products (around 50 million tons per year) had increased substantially in both developed and developing countries at the expense of beef and pork consumption (Monnikhof, 1997; Roenigk, 1999). The price, value and religious acceptability of poultry have been favourable for stimulation of this demand.

In South Africa, the poultry industry is the largest sector in meat production and the largest user of grain. Poultry meat is the most important source of affordable protein to the population at large and is thus popular, especially in lower income groups. It is also popular in the higher income group due to the attraction to diets that are lower in cholesterol.

There are currently more than 500 million broilers produced per year in the commercial sector in the Republic of South Africa, with another estimated 1 - 2 million produced in the informal sector (Du Toit, 2001). The present situation regarding household food security is related to national food security, as approximately 2.3 million people in South Africa, including children under 12 years of age, and pregnant and lactating mothers, may be regarded as malnourished (Du Toit, 2001).

Poultry production, being one of the most vibrant and viable systems of agriculture, stands out as an unique opportunity for both urban and rural dwellers to take up as an income-generating venture. In order to alleviate poor nutrition or malnutrition, small-scale poultry production can be done at household level in developing countries.

1.2 Socio-economic background

The poultry industry in Africa has undergone many changes, particularly over the last five years, due to erratic and decreasing rainfall, climatic disasters, e.g. droughts, cyclones, hurricanes and floods), civil wars, as well as political and monetary instability.

These have caused many African countries to experience a drastic decrease in agricultural and animal production. High levels of unemployment and underemployment, as well as the low purchasing power of many African currencies has exacerbated this situation. The average yearly income of an African was estimated at about US $665 in 1997 (Guèye, 2000). This income is insufficient to acquire food in adequate quantity and quality to satisfy the needs of their families. The above-mentioned factors result in animal protein deficits.

The human population in Africa is currently estimated to be 820 million (Guèye, 2000). The total poultry population of the continent was estimated as 1133 million chickens, 15 million ducks and 7 million turkeys in 1998, producing 1 781 701 metric tonnes (MT) of hens eggs, 2 269 000 MT chicken meat, 32 834 MT of turkey meat and 52 989 MT of duck meat. Commercial poultry products are also imported and exported. For example, 12 000 MT of poultry meat were estimated to have been exported from South Africa in 1999, whereas 87 000 and 10 000 MT of poultry meat were estimated to have been imported into South Africa and Egypt, respectively (Guèye, 2000).

In South Africa, it was estimated that by the year 2000, the low-inccome would account for 67% of the country's total protein needs. (Naude, 1992). By the year 2010, the same population sector is expected to increase from 32 million to 45 million (Naude, 1992). The projected growth in the South Africa population, and the increased standard of living since 1994, is likely to lead to a dramatic increase in consumption of poultry products.

1.3 Importance of feed cost in poultry production

In most African countries, the principal constraint to commercial poultry development is usually related to feed resources and feeding aspects.

Feed costs represent 60 - 80% of the economic inputs in the commercial poultry industry (Kleyn, 1992). Cereal grains, especially maize, represent the main energy component of commercial poultry rations.

The main problem, however, is that human consumption has priority for the use of cereals and many African countries are not even self-sufficient in cereals for human consumption. A surplus of cereals for poultry feeding is, therefore, generally not available. Cereals may have to be imported, requiring foreign exchange. Costs of imported feedstuffs rise steadily, especially during times of shortage. This has a negative impact on incomes of commercial poultry farmers.

Many African countries produce an assortment of both conventional and alternative feed resources and ingredients suitable for poultry, which may be under utilised (Agwanobi 1993, 1995; Eruvbetine & Afolami, 1996). Dried bakery product (DBP) may be one of these, and is discussed in further details in Chapter 2.

1.4 Size of poultry enterprises

The size of the poultry enterprises plays a role in the type of production. A majority of small-scale farms are usually "meat-orientated". This is largely due to the fact that most beginners start small-scale enterprises, and broiler enterprises requires less management skills and capital than layer enterprises (Guèye, 2000).

Poultry farming in Africa can be divided into two different types of production. Commercial poultry farming, which is found mainly in and around the towns and traditional family poultry farming in the rural areas. The commercial poultry sub-sector has become a considerable protein source for consumers, as well as a substantial source of income for poultry keepers. This sub-sector comprises large, medium and small-scale commercial poultry farming.

Small-scale poultry production in urban, peri-urban and rural areas makes minimal use of land, labour and capital. It is also able to utilise local resources in terms of feed and other production inputs. Consequently, it is a feasible option for meeting animal protein needs in the region, given current social economic and technological realities (Sinyangwe, 1999).

In Botswana, 29% of all eggs and 64% of chicken meat from commercial poultry enterprises were produced by small-scale enterprises and the remainder came from medium and large-scale commercial poultry enterprises (Guèye, 2000).

1.5 Research questions

- Can DBP be used in place of part of the grain usually fed?
  DBP as a waste product from bakeries is readily available in rural communities in South Africa, and its use might result in a significant reduction of feed costs.
- What poultry farming system and size would benefit?
  A sustainable poultry production system may be fully compatible with socio-economic conditions in South Africa. For the purpose of our study we will refer to a "small" poultry system as a venture with anything from 500 and 2 000 chickens.
- Would the choice feeding method (CFM) using DBP and commercial poultry ration, be more cost effective than feeding only a complete commercial ration?

Choice feeding method might be one of the valuable and practical methods of reducing the price of feed. Feasibility of this will have to be tested.

- What type of poultry production system could utilise DBP most effectively (layers or broilers)?

  Small-scale producers favour meat production, as start-up costs are lower. Because of egg production, the requirements for diets with balanced protein and minerals are more critical in layers than broilers. Broiler systems will, therefore, be chosen for this study.

1.6 Hypothesis

Dried bakery products can be cost-effectively used with commercial rations, using the CFM, without compromising performance of broilers produced in a small-scale commercial poultry enterprise.

1.7 Objectives

1.7.1 Primary objectives

To determine the relative feed costs after 42 days, of broilers fed DBP and commercial ration using CFM, in comparison to a control group fed commercial ration.

1.7.2 Secondary objectives

To evaluate the economic effects, costs and benefits, as well as the availability of DBP as an alternative feed ingredient for broiler diets.

To eliminate salt concentration as a confounder, which affects the free choice of birds offered DBP and commercial rations. This will be done by offering one group of birds a choice between DBP and low salt broiler starter ration and the other group a choice between DBP and broiler starter ration with a normal salt concentration.

To determine and evaluate the feed intake, body weight gain, feed conversion rate, as well as the mortality percentage of broilers given a choice between DBP and commercial rations, in comparison to a group fed on complete rations. To use scenario planning to assess the relative impact of extension messages to small-scale poultry farmers of substituting DBP as part of the broiler ration.

CHAPTER II

LITERATURE REVIEW

2.1 Dried bakery products as an alternative feed ingredient in broiler diets

Maize, wheat, barley and oats are the most commonly used energy-rich feedstuffs in conventional poultry diets (Summers *et al.,* 1968; Saunders *et al.,* 1969; Moran *et al*., 1970; Patterson *et al*., 1988; Vohra, *et al*., 1991; Cave & Burrows, 1993; Reddy & Quadratullah, 1996). Their production in Asia, Africa and Pacific nations has, however, never been adequate, either for human consumption or agricultural use. Consequently, there is a severe shortage of cereals for use in poultry feeds. Conventionally employed vegetable oil meals/cakes, (soybean, peanut, sunflower, sesamum and rape) and even animal proteins such as fish and meatmeal, are expensive and their supply inconsistent (Reddy & Quadratullah, 1996). There is a continuous search for alternatives to reduce poultry feed costs, and improve the efficiency of small-scale poultry units. An effort is thus being made to study the possibility of utilising agricultural, animal and industrial by-products for the nutrition of poultry (Fetuga *et al*., 1976; Dominguez, 1992; El Boushy, 2000a)

Over the last two decades research has been conducted world-wide on the suitability of various non-conventional feedstuffs in poultry rations. These include waste product from bakeries, tubers (sweet potatoes and cassava roots), shrub leaves (Leucaena, Calliandra, Sesbania); aquatic plants (Azolla, water hyacinths); insects (termites); fruit (palm-oil fruit, papaya, mangoes and guava) and even earthworms. Several studies have shown that these unconventional feedstuffs can serve as a viable alternative to maize in poultry diets (Yoshida & Morimoto, 1958; Hill *et al.*, 1960; Fetuga *et al*., 1976; Gerpatio *et al.,*1978; Job *et al*., 1979; Khajajern & Khajajern, 1985; Ravindran & Rajaguru, 1985; Daguro & Rivas 1987; Dominguez, 1992; El Boushy, 2000b), and can lead to reduced cost per kg of live weight. This could possibly reduce the total cost of production in small-scale systems (Eruvbetine & Afolami, 1996).

Waste product from bakeries, which is one of these non-conventional ingredients, is available in commercial quantities for animal feeding. The American Association of Feed Control Officials recognises this ingredient under the official name of “dried bakery product” (DBP).

DBP is a mixture of surplus and unsalable materials (cakes, stale bread, crackers, biscuits and even unbaked dough) collected from bakeries and other food processors. The products are collected, ground, mixed and dried to moisture content of 10% or less.

Results of feeding trials with dairy cattle, steers, rats, rabbits, chicks and laying hens indicate that this product is a satisfactory ingredient for animal and poultry feeds (Harms *et al*., 1966; Day & Dilworth, 1968).

In many areas of South Africa, where small-scale poultry enterprises exist, many bakeries, e.g. "Boerstra Bakery" which is one of the biggest suppliers of bakery products throughout South Africa, has a readily available source of stale bread.

Morrison (1959) (quoted by Damron, 1965) reported that DBP could be used instead of part of the grain usually fed to poultry. Damron *et al*., (1965) conducted two experiments to evaluate DBP for use in broilers. The first experiment was conducted to determine the effect of various levels of DBP on the performance of chicks. The second experiment was conducted to determine effects upon growth due to any variability of nutritive content in mill-run DBP. Diets were formulated using DBP at levels of 2.5, 5.0, 7.5 and 10.0%.

The results of these studies indicated that DBP was fairly uniform in composition over a period of time and supported good performance when used in broiler diets. The data from these studies also agreed with the results of the first experiment, in that DBP could be added at levels up to 10% of the diet without significantly altering the performance of chicks. Therefore, it was concluded that DBP might be added at levels of up to 10% of the diet. However, the only disadvantage of using DBP could be its higher level of salt (NaCl) and this may pose a problem in ration formulation in poultry feeds.

An experiment was later conducted by Day *et al*., (1968) using DBP at levels of 5, 10 and 15%. It was fed to broilers in battery and floor studies for 4 and 8 weeks respectively. Results of both studies, which used a computer program to calculate the exact proportion of dietary nutrients, indicated that DBP could safely be included in broiler diets at a 15% dietary level (Day *et al*., 1968).

In the same studies, an economic evaluation of DBP was made using the results from the large floor experiment and the computed cost of each diet. They found that the use of DBP resulted in a slight reduction in the feed cost required to produce 100 kg of broiler meat commercially.

Saleh *et al*., (1996) evaluated the use of high levels of DBP in diets for broiler chickens. A series of diets were formulated in which the DBP was incorporated at levels from 0 - 25% in increments of 5%. It was concluded that increasing the quantity of DBP in the diet from 0 - 25% had no adverse effects on body weight, feed utilisation, mortality, or calorie gain ratio at 21 and 42 days of age.

All the above-mentioned authors examined the use of DBP in commercial rations, whereas this study examined the use of DBP in the context of small-scale farmers. These farmers usually buy ready formulated rations, which are costly. The use of DBP was chosen for this study as a possible alternative feed source to supplement poultry rations for these small-scale farmers.

There are three research problems associated with this:

1. The first problem is that small-scale farmers in South Africa have no access to feed testing and the use of computers to formulate rations.

2. The second problem is the high levels of salt in DBP, and how this could be compensated for in the feed of broilers.

3. The third problem is the different ratios of protein, energy and minerals required for the different phases of growth i.e. starter (0 - 21 days), grower (21 - 35 days) and finisher (35 - 42 days). Consequently, the choice feeding system was examined in order to solve these problems in small-scale poultry enterprises.

2.2 Choice feeding method

Small-scale farmers are not sophisticated and mixing rations is difficult for them. A practical and viable way of balancing a variety of cost-effective feed ingredients in a ration, without using feed analysis and a computer, is by using the CFM.

In this method, domestic animals are allowed to balance their own diet with continuous access to a protein-vitamin-mineral concentrate and energy source such as whole grain (Blake *et al*., 1984; Kyriazakis, 1995; Munt *et al*., 1995).

The principle of CFM is that domestic animals, when given a choice between two or more appropriate feeds (a combination of which is nutritionally non-limiting), are able to select a diet that meets their nutritional requirements.

This is based on the principle that modern livestock is derived from wild ancestors, which have been naturally selected for making the best possible use of the resources available to them, and that domestication has not imposed any constraint on such an ability (Cowan & Michie, 1978a; Kyriazakis, 1995).

If animals in the wild are able to select a diet that meets their individual nutrient requirements, then animals of different characteristics (genotype or otherwise), kept in various environments, would be expected to select different diets appropriate to their individual needs when they are given a choice between feeds. Any changes in the animal's requirements, due to growth or physiological needs, would result in changes in their diet selection (Bradford & Gous, 1991a; Kyriazakis, 1995).

In broiler production there are three phases: starter, grower and finisher (North, 1990a; Le Roux, 2000). Previous authors did not indicate the role of DBP in each of these phases (Damron *et al*., 1965; Day *et al*., 1968; Saleh *et al*., 1996). Usually protein requirements are higher in phases one and two and energy requirements are higher in phase three. Choice feeding methods would be a possible answer, because small-scale farmers may use only two-phases (omitting the last phase - finisher ration) and birds themselves could then, by choice, eat more of the high protein starter ration in phase one and two and more of the DBP (high energy) in phase three. Broilers could also discriminate against the higher salt levels in DBP, by eating less of it, if its content in the ration is excessive to their needs.

Using the CFM, the problems presented by the variability in the nutritional contents of different batches could be overcome, since the animal would adjust its diet selection appropriately (Kyriazakis, 1995).

There has been interest in using CFM for poultry since the early part of the century when Kempster, (1916) and Rugg, (1925) (cited by Forbes & Shariatmadari, 1994), observed that free-choice laying fowls produced more eggs than those fed a single food and that white leghorns could balance their own diets.

It was confirmed in the 1930's that birds could select a balanced diet from several imbalanced foods. Graham (1932) and Funk (1932) (cited by Forbes and Shariatmadari, 1994) supported this view and free-choice feeding has received much attention since then. More recently, there has been a revival of interest in the method, which is a reflection of its attractiveness.

In most cases, the choice has been between one food that is clearly higher in protein content than required and another lower in protein. However, Forbes & Shariatmadari, (1994) reported that broilers selected from a range of nine different feedstuffs to provide a diet similar in composition to that normally recommended.

All experiments conducted on the CFM have the following common features:

- Offering free choice diets allows individuals opportunity to select the foods needed for maintenance and production, and may increase efficiency when compared to feeding a single diet (Rose *et al.*, 1986; Siegel *et al.*, 1997; Yo *et al.*, 1997).

- The feed intake in the choice situation depends on the nutrient requirement of the animal and feed composition, with little consideration for other factors such as genotype; chronological age or characteristics of the diets like smell, taste and texture (Emmans, 1978; Yo *et al*., 1997).

- Economic advantages could be expected from reduced handling costs and milling costs (Emmans, 1978; Rose *et al*., 1986; Yo *et al*., 1997).

- Factors affecting the diet selection by choice-fed broilers have been reported by Kubena *et al*., (1972), Emmans, (1978), Cowan & Michie, (1978b), Rose *et.al*., (1986), Sinurat & Balnave, (1986), Forbes & Shariatmadari, (1994), and Yo *et al*., (1997).

2.3 Economics, management and decision-making

2.3.1 Introduction

There is a logical sequence underlying the management of a production system. These decisions are based on the ideas of choice between alternatives; and the mechanism by which choices are made is often, if not always, based on economic analysis and evaluation (Casavant, 1999). The manager is the decision-maker who chooses among alternatives based on some form of economic reasoning, typically by comparing the benefits to the costs.

2.3.2 Gross margin concept

In crude terms: Profit = outputs less costs or inputs.

Nothing is more important in farming than the relationship of costs to income. The costs of a farm include feed, livestock, rent, labour, and machinery. To allocate costs to enterprises is frequently difficult and arbitrary, as they often overlap. The gross margin concept was introduced to circumvent this problem.

Costs in farming fall into two main categories: fixed costs and variable costs. Whether a particular cost item will be considered as fixed cost or a variable cost depends upon whether the input concerned is fixed or variable for the problem under consideration.

1. **Fixed costs** represent farming expenses of an "overhead" nature and do not change with output. Taxes, building depreciation, insurance, cash rent and interest payments for a farm are fixed costs. They are expenses, which must be paid even if nothing is produced; they are no greater under bumper yields and high production (Heady, 1965; Casavant, 1999; Penson, 2002).

2. **Variable costs** refer to farming expenses, which change with output; they do not occur if the farmer produces nothing; their amount depends on what is produced. If we use more fertilizer to produce more grain, the fertilizer costs go up with production. Seed, tractor fuel, repairs, feed, breeding fees, feeder stock and similar items represent variable costs. Unless production occurs, these expense items do not exist. Labour hired on a daily or monthly basis, or in some cases labour hired on a yearly basis, represents a variable cost. (Heady, 1965; Bucket, 1988; Anandajayasekeram *et al*., 1996; Casavant, 1999; Penson, 2002).

Only variable costs are important in determining whether the farmer should produce, or how much the farmer should produce. Fixed costs are unimportant in formulating decisions on different practices and different amounts of production. Fixed costs are the expenses, which relate to the fixed resources mentioned above; variable costs relate to the variable resources (Heady, 1965).

Livestock purchases are not regarded as variable costs, but are deducted when appropriate enterprise outputs are calculated (Heady, 1965).

Costs of production have a time dimension, which influences the nature of the decisions that can be made. The "short-run" is the length of time that is short enough for some costs and resources to be fixed. The "long-run" is anything longer than the short-run. Thus, if we define the short-run to be one year, then the long-run is anything beyond one year. In the long-run, all resources and claims on the business are variable (Penson, 2002). The total costs of a business in the short-run, can be divided into fixed costs and variable costs.

During the long-run planning period, all inputs are considered as variable costs. Thus, for the long-run planning periods, there are no fixed costs. There are, however, various lengths of planning periods depending upon the question under consideration. A farmer contemplating entering a farming business, for example, thinks of the costs of buildings, feed, livestock as variable costs. A farmer already operating will, in choosing a ration for his livestock, consider the costs of buildings and livestock as fixed, cost of feed will be considered variable. For an extreme "short-run" period, the farmer will probably consider all costs fixed, with the possible exception of purchased feed (Heady, 1965; Bucket, 1988; Casavant, 1999; Penson, 2002).

2.3.3 Economics of poultry farming systems

For the purpose of this work two types of poultry farming system will be defined, these are:

1. Large-scale
2. Small-scale

The economics of poultry farming depend to a great extend on the size of the farm.

2.3.3.1 Large-scale poultry farming

Large-scale intensive commercial systems are mainly found around towns and cities. Chickens are kept inside continuously. There are two alternatives:

- A floor system where chickens are kept on the ground.
- A battery systems where the chickens are kept on wire floors and have no contact with the ground.

This type of farming is capital intensive; as suitably designed buildings must be erected and only balanced rations are fed. As the poultry have to be kept under crowded conditions, attention must be paid to the prevention of disease. The system is suitable for both laying hens and broilers. From 10 - 19 broilers (depending on the level of sophistication) can be kept per square metre (Austic, 1990; North, 1990a; Appleby, 1992; Sainsbury, 2000).

Because of the intensive productivity, only highly productive chickens can be kept profitably. General management and disease prevention must be optimal at all times.

In large scale poultry enterprises, the land might be acquired by individuals using their own funds, or loans from the "Land Bank" through the Department of "Land Affairs". Building of the housing is not assisted by the government, it is usually done by a private company that charges building cost per sq meter including equipment, this also depends on the type of the house (longitudinal- ventilated house or cross-ventilated houses) and size.

The start up cost of this type of house is, therefore, very high and out of reach of small-scale producers (Glasser, 1997).

2.3.3.2 Small-scale farming systems

Small-scale farms have been defined in different ways. One definition is that they are household units that make most management decisions, control most of the farm labour supply and normally much of the capital as well. Since the family and the farm unit are the same, labour and capital expenditure decisions represent a choice between household and farm considerations. A more precise definition of small-scale farms is that they are complex interrelationships between animals, crops and farming families.

Another definition is that small-scale farms involve small-scale land holdings and minimum resources of labour and capital, from which small-scale farmers may or may not be able to derive a regular and adequate supply of food or an acceptable income and standard of living (Devendra, 1993; Sinyangwe, 1999; Guèye, 2001).

These definitions are not suitable for South African conditions, as small-scale poultry farms are not necessarily family or household linked, but may be community projects or small-businesses.

Koster & Coetzee, (1996) have defined a "small" poultry farming system as a venture with anything from 5 - 200 chickens. However, this amount of chickens would not provide a full-time poultry farmer with an independent income in South Africa, and would only be suitable for some one who had another source of income. For the purposes of this study, a small-scale, full-time commercial farmer with between 500 and 2 000 birds will be investigated.

This is a better definition for the purposes of this study where small-scale farms may be owned by community projects, small businesses or farmers. This will be considered an "emerging commercial farmer" or "small-scale" farmer who may have started gaining experience with a flock of 5 to 200 birds. Small-scale commercial poultry enterprises can be encountered in rural or peri-urban areas.

Small-scale commercial poultry farming is, however, not less important just because it is small. One can start small with minimum economic inputs and slowly expand and still be considered small-scale.

There are different types of small-scale commercial farming systems, they are:

Free range: The chickens roam about freely and there are almost no input costs but the return is also small (Koster & Coetzee, 1996).

Backyard (subsistence) venture: Where the chickens are confined within a fenced yard with overnight shelter (shelter can be removed). Pens can be made of corrugated iron and wire mesh (Koster & Coetzee, 1996; McCrindle, 1998).

Semi-intensive systems: Where a permanent structure with fenced yard is put in and the chicken can still go out during the day (Koster & Coetzee, 1996).

Intensive systems: Permanent structure (housing) designed for broilers to meet all requirements for intensive production (open sided house) (Koster & Coetzee, 1996).

For the purposes of this study, a small-scale broiler system will be defined as an intensive system with 500 – 2 000 birds.

In communal areas, the land is under the control of the chief and his tribal authority. The community shares most of the resources, such as labour, water and land. This is done under the supervision of the chief or a headman. In this situation, land is made available to the members of the community free of charge if they want to run small businesses, such as small-scale poultry farming (McCrindle, 1998).

The building of poultry houses may be financed by the government, through the Land Bank. Small-scale farmers may lease these buildings or pay off a loan from the Land Bank. Inhabitants in communal areas get water from state boreholes, therefore, the costs of land, and water will not be considered in the economic evaluation, as the costs are not comparable with those of commercial farmers. Electricity is already available in some communal areas and poultry farmers may have access to it. Every farm in the communal areas is a particular case.

These small-scale poultry farming systems in communal areas have some things in common:

- Fixed costs for land are not considered as input costs or capital costs because land is free of charge in most communal areas.
- The houses are built by the farmers using funds from the Land Bank or from their own finances. This can be considered a start up cost or capital cost.
- Variable costs (electricity, water, food and vaccines) differ from one farm to another.

2.4 Sequencing livestock systems research

While the characteristic of particular livestock systems may influence the methodology of livestock systems research, the terminology used and the sequencing of activities into phases is similar for all types of farming systems research (ILCA, 1990). The phases commonly identified are:

- Descriptive/diagnostic phase
- Design phase
- The testing phase, and
- The extension phase.

2.4.1 Descriptive/diagnostic phase

The main objective of the descriptive study is to describe the production system of each identified target group, to identify the target group for which the intervention is intended (ILCA, 1990). A small-scale poultry production in rural areas was chosen for the purpose of our study

2.4.2 The design phase

The focus in this phase is on technologies that are compatible with the resources and objectives of the producer and consistent with the system features identified during the descriptive/diagnostic phase (ILCA, 1990).

2.4.3 The testing phase

The objective is to test, using on-farm trials, the solution proposed during design (ILCA, 1990).

The descriptive/diagnostic phase, the design phase and the testing phase are described in detail in Chapter 3 while the extension phase will be described in more detail below.

2.4.4 The extension phase

The objective of the extension phase is to assess the impact of new technology in the wider community.

2.4.4.1 Definition

"Agricultural extension" is a difficult term to define, precisely because it is organised in different ways to accomplish a wide variety of objectives. The term therefore has a variety of meanings to different people, but from this spectrum of different interpretations, there appear to be several common elements:

Extension is an on-going process of getting useful information to people (the communication dimension) and then in assisting those people acquire the necessary knowledge, skills and attitudes to utilize effectively this information or technology (the educational dimension). Generally the goal of the extension process is to enable people to use these skills, knowledge, and information to improve their quality of life (Swanson & Claar, 1984),

According to Ban, (1988) and (1996), extension involves the conscious use of communication of information to help people form sound opinions and make good decisions.

The term, agricultural extension, narrows the focus and defines the areas to which the extension process is applied. Swanson & Claar, (1984) defines agricultural extension as a service or system which assists farm people, through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their level of living, and lifting the social and educational standards of rural life.

2.4.4.2 Importance of extension

The past experience of agricultural extension demonstrates that the function of extension is essential to the agricultural development process. Farmers cannot successfully adopt a new technology unless they are aware of it and learn how to incorporate it into their farming systems.

Agricultural production has increased substantially in many countries since the second World War. Returns on investments in agricultural research and agricultural extension have been studied in industrialised, as well as the less industrialised countries. Most studies report a return of between 30 and 60 per cent, which is probably more than returns on other investments in agriculture, such as irrigation (Ban, 1988). Many countries, especially in Africa, have needed large amounts of money for food aid in recent years. It is quite probable that fewer people would have died from hunger, and expenses would have been lower, if more investments had been made in agricultural research and extension somewhat earlier.

2.4.4.3 Communication in agricultural extension

Agricultural communicators define technology transfer as the communication task of transferring farming information from the researcher, and then transmitting the farmers' problems back to the researcher. Although a two-way flow of communication is essential, technology transfer also involves helping farmers to learn how to use new technology to achieve their goals (Bembridge, 1991).

Extension workers need to use the full range of extension methods for different purposes. The astute use of mass media alerts farmers to an awareness of new ideas and farming practices, and informs them of coming events and activities, while small group discussions and farmers' days give farmers the confidence and technical detail to change farming practices.

In agricultural extension the communicator needs to concentrate on the results achieved. These results include changes in attitude, increases in the farmer's knowledge and skill level, changes in farming practices and increased production and profitability per unit or area (Bembridge, 1991).

Extension communication involves interaction between extension workers and individual farmers either directly through word of mouth, or indirectly through groups and mass media.

Figure 2.1 shows the SMCRE model that is a very simplistic view of communication when applied to agricultural extension programs. The element of SMCRE (Sender, Message, Channel, Receiver and Effects) are important in analysing and planning communication strategies for agricultural extension programs.

Figure 2.1: The SMCRE model of communication (after Bembridge, 1991)

No single communication system can do all things for everybody. Various alternative approaches exist and the most applicable can be chosen by identifying the specific target group. For the purpose of our study a successful communication method rests on a proper situational and cost-benefit analysis, prior to intervention, with continuing evaluation and modification thereafter.

The team of communicators should preferably include a veterinarian and a sociologist or socio-anthropologist as the socio-economic status and cultural characteristics of the target community are important. An intervention team is then mobilised and contacts made with key persons in the community in order to choose the best time, place and scope of the intervention. After the intervention has occurred the team meets again to discuss evaluation. This includes direct evaluation, i.e. rapid appraisal applied a few months or years afterwards, to assess whether intervention had the desired results (McCrindle, 1998).

The process is summarised in Figure 2.2.

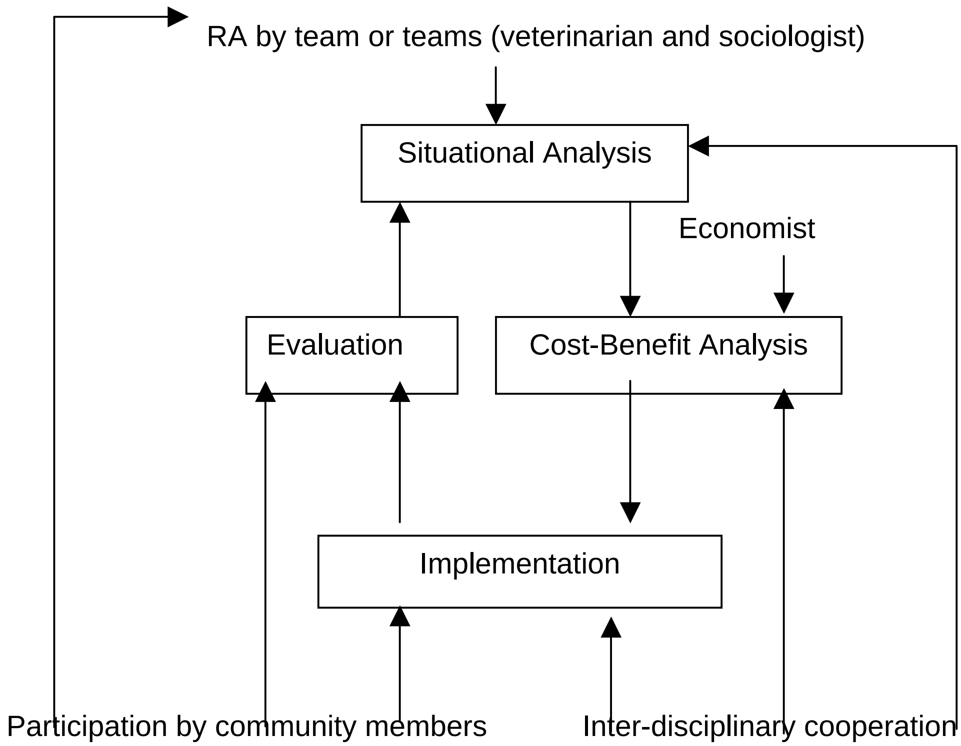

Figure 2.2: Schematic representation of the steps for successful communication in a low-income community (McCrindle,1998)

Communication is a two-way process. Feedback means that the message is 'fed back" by the receiver (farmer) to the source (extension worker). Sending messages is only one third of the job. The other two thirds are finding out the effect advice and recommendations had on farmers. These tell the extension worker whether the farmer has understood the message or not and enable him, if necessary, to adjust his message and channel it to meet the particular needs of the farmer and the local situation.

2.5 Balance of nutrients

Commercial poultry rations are known as "complete rations"; that is, they contain all essential ingredients for the birds to perform well, whether it is in growth, feather renewal, egg production, or the production of meat. For the most part, because the bird is closely confined to its quarters, it has no access to another source of feed material. What it needs, it must get from the feed it is given each day.

Certain parts of this feed come from the common and major feed ingredients such as cereal grains, protein and fat supplements, certain mill by-products and major minerals. In most cases, a mixture of these ingredients would not satisfy the bird's nutritional requirement, nor would it be economical. Certain vitamins, minerals, by-products and other ingredients must be added to 'balance" the diet.

In the present study, feed will be given on free choice, it is, therefore, important to have knowledge on the nutrient composition of the conventional broiler feed, as well as that of DBP.

2.5.1 Nutrient composition of conventional broiler feed

2.5.1.1 Energy in broiler rations

Energy is one of the most important factors in broiler rations and plays an important role in determining the performance of the birds. The main reason is that birds will eat sufficient feed to satisfy their energy requirements and this is one of the main factors limiting intake. If the energy intake (feed intake) of the bird changes, so does the intake of protein (amino acids), vitamins and minerals. This means that the ratio in which these are supplied in relation to the energy content of the diet is absolutely critical if so as to ensure that the bird receives adequate amounts of nutrients for any phase of its growth (Plumstead, 1997; Sainsbury, 2000).

The primary sources of energy in broiler feeds are carbohydrates and fats. However, when protein is fed in excess, it too may become a source of energy. Feeding protein for energy is uneconomical and the balance between carbohydrates, fats and protein in the diet must be carefully constructed.

The calorie-to-protein ratio of the diet is important for its influence on growth, feed conversion, and carcass composition. When the levels of productive energy are increased in relation to the protein level, live weight and body fat increase. Carcass fat increases when the energy content of the diet and energy intake increase (Brown & McCartney, 1982).

As the calorie-to-protein ratio increases, the energy intake and the body weight increase and body water decreases. A wider calorie-to-protein ratio could be tolerated at any protein level when the portion of energy provided by fat was increased (Donaldson *et al*., 1956).

Increasing the dietary protein increases carcass protein and decreases carcass fat of broilers. Little or no improvement in weight is achieved when dietary protein is raised above 20% (Summers *et al*., 1968; Brown & McCartney, 1982). Less dietary protein and more dietary energy was shown by Donaldson *et al*., 1956, to be required per unit of gain, as the calorie-to-protein ratio is increased

2.5.1.2 Protein in broiler ration

It is not the broiler's requirement for total protein that is important, but the daily need for individual amino acids.

A three-stage feeding program tends to equalise the necessary protein requirement during starting, growing and finishing periods and matches the feeding schedule involved with the metabolisable energy (ME) program, as shown in Table 2.1.

Table 2.1: Three-stage feeding programme in broilers (Le Roux, 2000)

	THREE-STAGE PROGRAMME		
	STARTER	**GROWER**	**FINISHER**
Feed type	Crumble	Pellet	Pellet
Age (days)	1 - 21	22 - 35	36 – 42
% protein	22	20	18
Energy ME MJ/kg	12.90	13.35	13.81

2.5.1.3 Amino acid requirement of broilers

Dietary amino acid deficiencies affect the amount and proportions of tissues synthesised by chicks. The effects vary between amino acids and with the severity of the deficiency (Okumura & Mori, 1979; Sibbald & Wolynetz, 1986; Schutte & Pack, 1995).

Five of the 22 amino acids are critical in poultry diets as others are usually supplied adequatelly by a combination of feedstuffs (North, 1990b). The five critical amino-acids are: arginine, lysine, methionine, cystine and tryptophan.

Lysine is often one of the limiting amino acids in broiler diets and usually selected as the reference amino-acid (AA) for three primary reasons (Baker & Han, 1994):

1. Its analysis in feedstuffs, unlike tryptophan and sulfur AA (SAA), is relatively simple and straightforward (Baker & Han, 1994).
2. A considerable body of data exists for the digestible lysine needs of poultry; and (Acar *et al*., 1991; Baker & Han, 1994), and
3. Unlike several other AA, e.g., methionine, cystine, and tryptophan, absorbed lysine is used only for protein accretion (Baker & Han,1994; Edwards *et al*., 1999).

Breast meat development is sensitive to dietary lysine content, as muscle protein is high in lysine and the contribution of breast muscle to total carcass meat is considerable (Halvorson & Jacobsen, 1970; Moran & Bilgili, 1990; Si *et al.*; 2001). Breast meat contributes about 30% of total carcass meat and as much as 50% of total edible carcass protein (Si *et al*., 2001). As broiler strains have been increasingly selected for breast meat yield, providing optimum levels of lysine, as well as other amino acids has become of concern.

The contribution of lysine to improved carcass yield is very substantial. The effect of dietary lysine on carcass characteristics and composition of broilers (28 - 42 days of age), in addition to live performance were studied by Moran & Bilgili (1990). They found that feed efficiency and breast meat yield improved and percentage of carcass fat decreased as lysine levels increased from 0.85 to 1.05% in diet.

The requirements for amino acids in the three phases of broiler sets are shown in Table 2.2.

Table 2.2: Amino acid requirements of broiler rations (North, 1990b)

AMINO-ACIDS	RATION		
	STARTER	GROWER	FINISHER
Arginine (%)	1.44	1.20	1.00
Glycine +serine (%)	1.50	1.00	0.70
Lysine (%)	1.20	1.00	0.85
Methionine (%)	0.50	0.38	0.32
Methionine **+** Cystine (%)	0.93	0.72	0.60
Tryptophane (%)	0.23	0.20	0.17

2.5.1.4 Vitamin requirements of broilers

A vitamin is now generally accepted to be an organic compound which is a component of natural food, but distinct from carbohydrate, fat, protein and water. It is necessary in much smaller quantity to enable the bird to live, produce meat and reproduce efficiently. When absent from the diet or not properly absorbed or utilised, it results in a specific deficiency disease or syndrome (Scott *et al.*, 1976; North, 1990c).

Classically, the vitamins have been divided into two groups based upon their solubilities in either fats and fat solvents or in water. The fat-soluble vitamins A, D, E, and K are found in feedstuffs in association with lipids.

The fat-soluble vitamins are absorbed along with the dietary fats, apparently by mechanisms similar to those involved in fat absorption. The water-soluble vitamins required by the chicken are vitamins B1, B2, B6, B12, nicotinic acid, panthothenic acid, folic acid, biotin and choline (Scott *et al.*, 1976). The vitamin requirements of broiler rations are given in Table 2.3.

Table 2.3: Vitamin requirement of broiler rations (North, 1990c)

VITAMIN	AGE OF BROILERS			
	0 – 21 DAYS		22 DAYS - Market	
	Per lb	per kg	per lb	per kg
Vitamin A (IU)	682	1.500.	682	1.500
Vitamin D3 (IU)	90.9	200	90.9	200
Vitamin E (IU)	4.6	10.0	4.6	10.0
Vitamin K (mg)	0.23	0.5	0.23	0.5
Thiamin (mg)	0.8	1.8	0.8	1.8
Riboflavin (mg)	1.6	3.6	1.6	3.6
Pantothenic acid (mg)	4.6	10.0	4.6	10.0
Niacin (mg)	12.3	27.0	12.3	27.0
Pyridoxin (mg)	1.4	3.0	1.4	3.0
Biotin	0.07	0.15	0.07	0.15
Choline (mg)	591	1.300	386	850
Vitamin B12 (mg)	0.004	0.009	0.004	0.009

2.5.1.5 Mineral requirements of broilers

According to Scott, *et al.*, (1976), eight of the thirteen inorganic elements are cations. These are calcium (Ca^{2+}), sodium (Na^{+}), potassium (K^{+}), magnesium (Mg^{2+}), manganese (Mn^{2+}), Zinc (Zn^{2+}), iron (Fe^{2+}) and copper (Cu^{2+}). Five are either anions, or are usually found in anionic groupings. These are chloride (Cl^{-}), iodide (I^{-}), phosphate (PO_4^{3-}), molybdate (MoO_4^{2-}) and selenite (SeO_3^{3-}). (Na^{+}) and (Cl^{-}), being the target for selection in this experiment, will be given more emphasis.

<u>Salt (Sodium Chloride)</u>

Like air, water and sunlight, NaCl has always been rated as important throughout the ages in the feeding of livestock and poultry. Salt functions in a variety of ways, in the avian species. Health, growth, production, and life itself depends on the presence of salt and its component parts, sodium and chloride. Digestion, respiration, and many other body processes involved are greatly impaired when salt is withdrawn from rations. Most early-formulated rations contained

1% of NaCl. As early as 1926, investigators observed that chicks receiving high cereal rations grew slowly with no added salt. The addition of 0.5% NaCl produced satisfactory growth and as much as 1% did not prove detrimental when diets contained ground corn, wheat, wheat by-products, ground oats and alfalfa meal. In most countries the various salt forms are differentiated by colour, with common salt being a natural white colour, and iodised salt being red (Leeson, 1997).

Sodium and chloride ions in the body perform vital functions in the maintenance of osmotic pressure, water and acid-base balance. Sodium (Na) as the chloride (Cl) is found chiefly in blood and body fluids. Sodium is connected intimately with maintenance of membrane potentials, cellular transport processes, and regulation of hydrogen ion concentration of blood. Chloride, the major mineral anion in extra cellular fluid, plays a role in fluid and ionic balance (Ewing, 1951; Schaible, 1976; Fisher, 1986; Austic,1990; Fowler, 1996; Jordan 1996; Austic & Scott 1997).

Natural feedstuffs usually require supplemental feeding of salt (NaCl) to satisfy the bird's requirement for sodium and chlorine.

The desired amount of salt needed for high-energy rations was found to be approximately 0.25 - 0.35% above that found in the natural ingredient (Patrick, 1980; Leeson & Summer, 1991; Austic & Scott, 1997; Leeson, 1997).

Studies with purified diets showed that sodium was the most important part of salt. Formulation for poultry diet is to a minimum sodium level of around 0.15 - 0.2%, the minimum requirement being about 0.12% below this level e.g. at 0.10% broiler chick fail to grow optimally (Patrick, 1980; Austic & Scott; 1997). In controlled environment housing, it is necessary to maintain constant dietary levels of sodium and chloride since variations will result in changes in water consumption that may lead to wet litter if the ventilation management is not altered quickly enough to accommodate the additional moisture in the atmosphere (Brown & Jordan, 1999).

Animals receiving diets deficient in sodium not only fail to grow, but also develop softening of bones, corneal keratinisation, gonadal inactivity, adrenal hypertrophy, impairment of food utilization (Schaible, 1976; Fowler, 1996; Austic & Scott 1997). Poultry can tolerate excesses of salt better in feed than in water, but large amounts of salt in the ration are toxic to chickens and readily result in wet droppings and wet litter (Schaible, 1976; Patrick, 1980; Austic & Scott 1997)

The lethal dose is approximately 4g/kg body weight. Young chicks appear to be more susceptible to toxic effects of salt than are older chickens. Signs of salt intoxication include inability to stand, intense thirst, pronounced muscular weakness, and convulsive movements preceding death. There are lesions in many organs, particularly haemorrhages and severe congestion in the gastrointestinal tract, muscles, liver, and lungs (Fowler, 1996; Austic & Scott 1997; Brown & Jordan, 1999).

Other minerals

Potassium is a necessity, but ordinary poultry rations are seldom deficient in this element. Conventionally, K is not supplemented in poultry rations (North, 1990c).

Calcium and phosphorus are closely associated in metabolism, particularly in the formation of bone. In the growing chicken the major portion of the calcium in the diet is used for bone formation (Scott *et al*., 1976; Boling *et al*., 2000a). In addition to its role in bone formation, phosphorous has important functions in the metabolism of carbohydrate and fats; it enters into the composition of important constituents of all living cells and salts formed from it play an important part in the maintenance of the acid-base balance. The calcium:phosphorus ratios needed for normal results in growing chicks varies between 1.5:1 and 2.2:1. A ratio of 2.5:1 appeared borderline while a ratio of 3.3:1 was found to be disastrous, producing rickets and others leg abnormalities (Scott *et al.*, 1976).

The National Research Council (NRC) (1994) recommends 10 and 9 g/kg of Ca and 4.5 and 3.5g/kg of available phosphorous (non-phytate P) from 0 - 3 and 3 - 6 weeks respectively.

Cereal grains and oilseed meals both have a relatively high content of P, however, up to 80% of the P is present as phytic acid. This poses a problem to nonruminant animals because they do not have sufficient intrinsic phytases needed to hydrolyse phytic acid complexes (Boling *et al.*, 2000b; Yan *et al.,* 2001). The low availability of P in plants poses problems both economically and environmentally. Economically, phosphorus is the third most expensive component in non-ruminant diets after energy and protein. A large amount of consumed P is excreted in the faeces and urine because of its high unavailability (Boling *et al*. 2000b).

A study conducted by Edwards & Veltman (1983) showed a higher incidence of tibial dyschondroplasia (TD) at levels of higher P and lower Ca. They also found that TD could be induced in young broiler chicks by manipulating the dietary levels of these two minerals. The mineral requirements of broiler rations are given in Table 2.4.

Table 2.4 Mineral requirements for broiler rations (North, 1990c)

MINERAL	AGE OF BROILER IN DAYS					
	0 - 21			22 – Market		
	%	Per Ib	Per kg	%	Per Ib	Per kg
Calcium (%)	0.95			0.90		
Phosphorus, total (%)	0.75			0.67		
Phosphorus, available (%)	0.45			0.40		
Salt (%)	0.35			0.35		
Sodium (%)	0.15			0.15		
Potassium (%)	0.40			0.35		
Manganese (%)		27.00	59.00		27.00	59.00
Magnesium (%)		28.00	600.00		273.00	600.00
Selenium (%)		29.00	0.15		0.07	0.15
Zinc (mg)		30.00	40.00		18.00	40.00

2.5.2 Nutrient composition of DBP (non-conventional) broiler feed

In the studies by Saleh *et al*., (1996), DBP was obtained from a local blending facility and subjected to analysis to determine the nutrient composition (Table 2.5). The energy content of the product was estimated from its proximate composition. Nutrient composition values for other ingredients were based upon values reported by NRC (1994), adjusted to actual crude protein and moisture content for corn and soybean meal.

2.5.2.1 Variation in nutrient content of samples of dried bakery product

Like many by-product feeds, variability of nutrient content is of concern for those who contemplate using this product (DBP). Because DBP has been shown to vary considerably in sodium content, samples should be constantly assayed to insure that excessive dietary sodium levels do not occur, especially if one considers using relatively high levels of the product (Waldroup *et al*., 1982; Dale *et al*., 1990; Saleh *et al*., 1996).

Table 2.5: Analysis of dried bakery products (Saleh *et al.*, 1996)

NUTRIENT	% BY ANALYSIS
Moisture	8.11
Crude protein	12.53
Ether extract	11.04
Crude fibre	2.25
Calcium	0.28
Phosphorus	0.52
Ash	4.80
Sodium	0.93
Chloride	1.37
Linoleic acid	1.71
Methionine	0.14
Cystine	0.20
Lysine	0.38
Tryptophan	0.01
Threonine	0.45
Isoleucine	0.53
Histidine	0.22
Valine	0.70
Leucine	1.02
Arginine	0.45
Phenylalanine	0.50
Glycine	1.00
Serine	0.76
Total metabolizable energy (TME, MJ/kg)	15.4

2.6 Mycotoxins

The quality of food and feedstuffs is normally measured by the nutritional value or physical characteristics. However, contamination by micro-organisms, which utilise food or feed as a source of energy, can result in significantly lower yields and feeds that are spoiled can have lower than normal nutrient values.

Foods and feeds manufactured from crops infected by fungi can become contaminated with toxic metabolites, including mycotoxins produced by the fungi and phyto-alexins produced by the host plant in response to infection (Shama & Salunkhe, 1991).

It is estimated that 25% of food and feedstuffs worldwide are contaminated with mycotoxins. Aflatoxins, ochratoxins, fumonisins and trichothecene are the most commonly seen mycotoxins in commercial poultry and are often encountered at alarming concentrations in different parts of the world (Osborne *et al*., 1982; Hollinger & Ekperigin,1999; Raju & Devegowda, 2000). These four mycotoxins are produced by *Aspergillus flavus*/*parasiticus*, *Aspergillus ochraceus, Fusarium moniliforme and Fusarium sporotrichoides*/*tricinctum* respectively, under different environmental conditions. However, their co-occurrence in a single foodstuff is not unlikely, as foodstuffs are exposed to a variety of climatic conditions in the field and during transit and storage (Pitt & Udagawa, 1980; Huff & Doerr, 1981; Raju & Devegowda, 2000). Also, grains and oilseed by-products, often used in poultry rations, are derived from crops grown in different climatic conditions. Thus, mixed feeds, made from foodstuffs contaminated with individual mycotoxins, may have all the mycotoxins present in different individual ingredients. Simultaneous feeding of broiler chickens with any two of these mycotoxins has been reported to exert synergistic effects (Huff & Doerr, 1981; Kubena *et al*., 1990; Raju & Devegowda, 2000).

Environmental factors have a major impact on the growth of fungi and play a critical role in the epidemiology of mycotoxicosis. In general, the conditions that favour mold growth include moisture greater than 13%, relative humidity in excess of 70%, temperature greater than 12.8^{o}C, readily available nutrients, a pH above 5, and the presence of oxygen (Paster & Lister, 1982; Kautz, 1998). There would be no mycotoxin production and no incidence of mycotoxicosis if environmental factors were such that they prevented the growth of fungi.

Fungal growth is required for mycotoxins production in grain, but this growth may or may not produce visible damage. Fungi can infect and grow in grain prior to harvest, during storage or after inclusion in finished feeds. Many mycotoxins are stable during milling and feed storage, so toxins can be present in grains after the fungi that produced them are dead.

Aflatoxins and aflatoxicosis, fumonisins and incidences of fumonisin toxicity predominate in areas of the world with warm climates. Maize, one of the main components of poultry feed, can be contaminated with a variety of mycotoxin producing fungi. Aflatoxins are seldom a problem in South Africa maize. Imported maize from the USA or Argentina, however, tends to be associated with aflatoxins (CSIR,1997).

In certain geographic regions of South Africa where there is a high incidence of oesophageal cancer, F. *moniloforme* has been implicated as the causative agent due to high incidence of this mold in home-grown corn (Marasas *et al.,* 1981; Henry & Wyatt, 2001). *Fusarium subglutinans* is also regularly isolated from maize in South Africa. This fungus is known to produce moniliformin which causes progressive muscular weakness, respiratory distress, cyanosis, coma and death in poultry (CSIR, 1997). *Fusarium graminearum*, capable of producing zearalenone and deoxynevalenol (also known as vomitoxin), is also occasionally found in maize in South Africa. Poultry, however, tend to be more tolerant to these mycotoxins than other animals. Ochratoxin and zearalanone and their toxicoses predominate in cooler climates. Other intoxications are seen less frequently

Losses due to fungal infestation are not only experienced by the grain producer, but also by the poultry farmer. Grain crops unsuitable for human consumption are normally used for animals, such as poultry. Mycotoxins are not necessarily removed from the food chain and can accumulate in the body of the animal.

Losses for poultry producers are caused not only by acute toxicity, but also by poor performances. In susceptible animals, disease is usually initiated after the animal has ingested feeds containing a toxic dose of mycotoxin. Expression of the disease varies. It depends on the organ system involved, and on the types, doses, and combinations of mycotoxins ingested. Signs and symptoms range from death to skin lesions or signs and symptoms of hepatoxicity, nephrotoxicity, neurotoxicity or genitotoxicity. Mycotoxins are also carcinogenic, mutagenic, or teratogenic and can have adverse effects on the immune system (Smith & Hamilton, 1970; Hollinger & Ekperigin, 1999; Marijanovic *et al*., 1990).

Since DBP derives from wheat, which is a grain, careful attention should be taken during storage to prevent the growth of fungi by controlling all environmental factors. Quality control procedures involve monitoring mycotoxins.

2.6.1 Aflatoxins

Aflatoxins are highly toxic and carcinogenic mycotoxins are produced by *Aspergillus flavus* and *Aspergillus parasiticus.* Sixteen different aflatoxin B1, aflatoxin B2, aflatoxin G1, and aflatoxin G2, and other aflatoxins usually occur together in feeds and grains, such as wheat, corn, soybeans and sorghum (Miazzo *et al.,* 2000). Aflatoxin B1 (AFB1) is the most toxic of the aflatoxins and is produced in greater quantities than any of the others (Hoerr, 1997; Hollinger & Ekperigin, 1999). They also occur in mouldy bread, fortunately this is usually easily visible.

In poultry, (AFB1) is associated with liver damage, poor performance, and immunosuppression. Livers characteristically show biliary and nodular hyperplasia and are pale and enlarged as a result of aflatoxicosis (Kubena *et al*., 1990; Phillips *et al*., 1995). In broilers the effects of exposure to aflatoxins are depressed growth rates, decreased efficiency of feed utilization, increased mortality, increased condemnations, and non-thriftiness (Tung & Hamilton, 1973; Hollinger & Ekperigin, 1999; Miazzo *et al.*, 2000).

Aflatoxin may remain in poultry meat after slaughter and constitute a human hazard.

2.7 The situation in the Republic of South Africa

Surprisingly no information is available regarding the feeding of birds with potential available energy-rich feeds (milling by products, roots, tubers, molasses, mango, seed, kernel, salseed meal, etc.). The cost of conventional raw feed materials (maize, wheat, oil, fish meal, etc.) is continually increasing in South Africa. Bakery waste in the form of stale bread (white and brown) from bakeries in certain areas of the country (a possible suitable alternative feed ingredient) will positively impact on resource-poor rural households.

There is, also, little information on the use of the choice feeding system for poultry in South Africa. Olver & Jonker (1997) conducted an experiment on the effect of choice feeding on the performance of broilers. They found that free choice feeding was more profitable than feeding complete mixed food such as mash or pellets, and the main advantage of choice feeding appears to be the economical savings of feeding whole grains as the energy source.

CHAPTER III

MATERIALS AND METHODS

3.1 Model system and justification of the model

If one assumes that all the management factors are controlled satisfactorily, feed consumption, protein and mineral requirements in layers depend to a major degree upon size and breed of hens, effect of environmental temperature, stage of production and energy content of the diet (Young, 1976; North, 1990). Diet formulation is much more critical for productivity in layers than it is for broilers because the content of nutrients may vary depending on the proportion of different breads. The DBP, should, therefore, preferably be used for broiler production.

A total of 570 day-old male broiler chicks (Ross) were used in this experiment. Broiler chicks were purchased and transferred from the National Chicks Hatchery at Boschkop near Pretoria, to the environmentally controlled poultry house at Onderstepoort where the experiment was conducted.

The DBP is low in protein. To compensate for the low protein level, a starter ration was used in the two CFM groups throughout the 42 days. In the grower and finisher phases, birds have a higher requirement for energy and it was anticipated that they would then choose to consume more DBP. Starter ration is more expensive than grower or finisher rations, and the study needed to determine whether DBP use would still result in savings in feed costs.

3.2 Experimental design

The study was one way factorial design with 3 treatments, 5 replicates / treatment, with a total of 570 day-old male broiler chickens. This resulted in a total of 190 birds per treatment, which was divided into five replications of 38 birds per replicate (Table 3.1).

The three dietary treatments consisted of:

- **TREATMENT A**: Normal commercial feed in two feeding phases: starter was presented in a mash form (1 - 21 days), and grower in the form of pellets (22 - 42 days). Treatment A served as control.

- **TREATMENT B**: Normal commercial starter ration (mash) for 7 days, followed by starter ration with normal salt concentration in a mash form (S1) plus DBP1 from 7 - 42 days, using the CFM.

- **TREATMENT C**: Normal commercial starter ration (mash) for 7 days, followed by starter ration in a mash form with a lower salt percentage (S2) plus DBP2 from 7 - 42 days, using CFM.

Table 3.1: Study design

REPLICATES	NUMBER OF BIRDS IN EACH TREATMENT GROUP			TOTAL NO. OF BIRDS
	TA*	**TB****	**TC*****	
1	38	38	38	**114**
2	38	38	38	**114**
3	38	38	38	**114**
4	38	38	38	**114**
5	38	38	38	**114**
TOTAL	**190**	**190**	**190**	**570**

TA* **=** Treatment A

TB** = Treatment B

TC*** = Treatment C

In the literature previously quoted, the choice has been between one feedstuff which is higher in protein or energy content than required and another that is lower in protein or energy content. The DBP is known to have a high salt content, low protein and similar energy content to commercial starter rations (S), and was given using the CFM to groups TB and TC. The feeds DBP1 and DBP2 were identical but have been given different names to make it easier to explain differences in feed intake between the two groups TB and TC.

It was anticipated that the ratio of DBP to starter ration, consumed by the birds, would be influenced by protein, energy and salt concentration. Salt (NaCl) concentration being a limiting factor in broiler rations was also considered as a target for selection in this experiment. Therefore, S2 had a lower salt content than S1. This should show whether the high salt concentration is a reason for birds refusing or choosing DBP, rather than the commercial starter ration.

Literature has indicated that probably either energy or protein was the most important factor for choice of ration, when the CFM was used (Holocombe *et al*., 1976a; Leeson & Summer, 1978; Brody *et al*., 1984; Emmerson *et al*., 1990; Emmerson *et al.*, 1991; Forbes & Shariatmadari, 1994; Yo *et al.*; 1997; Olver & Jonker; 1997).

This study design would show how the ratio of DBP:starter ration, varies over a 42 day period and whether the ingredients (protein, energy or salt) appear to have an influence on the birds' choice. The economic factors involved would also be calculated from weekly data on feed consumption and growth of broilers in the three groups TA, TB and TC.

3.2.1 Allocation procedure

The poultry house was partitioned into 16 compartments (pens) and 15 of these (five replicates per treatment), were used for the experiment. A total of 570 male broiler chicks were divided into 15 groups of 38 birds each and randomly assigned to the 15 pens (see Table 3.2**).** Stocking density is discussed in Section 3 under project management.

Table 3.2: Allocation of different diets / treatments (TA, TB and TC) in different pens

3D*	**3C**	**4D**	**4C**
3A	**3B**	**4A**	**4B**
2B	**2A**	**1B**	**1A**
2C	**2D**	**1C**	**1D**

3D* = pen with no birds.

Blue = Treatment A

Red = Treatment B

Green = Treatment C

3.3 Experimental procedures

3.3.1 Pre-experimental period

Chicks were fed on a complete starter diet in mash form during the first seven days. The position of the feeders were the same in each pen and remained unchanged during the entire experimental period. Free access to feed and water was allowed through this period. At seven days of age birds were individually weighed.

3.3.2 Experimental period

3.3.2.1 Procedures

The experimental period started when broilers were seven-days old. Three dietary treatments (TA, TB and TC) were assigned to pens in each of the five blocks, i.e. each treatment was replicated five times. The composition of the rations used for TA, TB and TC, as well as their calculated nutritive values, are shown in Tables 3.3, 3.4, 3.5, 3.6, 3.7 and 3.8.

3.3.2.2 Composition of rations used in different treatment groups

The constituents of the commercial grower ration, as is, used for group TA, are given in Table 3.3.

Table 3.3: Composition of grower ration used in group TA

INGREDIENT (As is)		%
1.	Maize fine	68.90
2.	Milling by product	4.50
3.	Sunflower oil cake	13.00
4.	Soya Oil Cake	9.00
5.	Salt	0.32
6.	Choline-chloride liquid	0.08
7.	Mono calcium phosphate	1.80
8.	Limestone	1.53
9.	Synthetic amino acids	0.58
10.	Salinomycin	0.05
11.	Flavomycin	0.04
12.	Vitamin mineral premix	0.20
	TOTAL	**100.01**

The constituents of the commercial starter rations (as is), S1 and S2 and are given in Tables 3.4 and 3.5 respectively.

Table 3.4: Composition of starter ration S1, used for group TB, and as a starter ration for all groups during the first seven days after hatching.

INGREDIENT (As is)		%	MIX (kg)
1.	Yellow Maize 8.0 %	60.59	610.00
2.	Bran 15%	1.49	15.00
3.	Local Fish	4.97	50.00
4.	Soya Oil Cake 47%	24.83	250.00
5.	Sunflower Oil Cake 38%	4.97	50.00
6.	Lysine HCL	0.11	. 1.10
7.	DL Methionine	0.17	1.74
8.	L Threonine	0.09	0.90
9.	Monocalcium phos	0.79	8.00
10.	Limestone	1.39	14.00
11.	**Salt**	**0.35**	**3.50**
12.	Vitamins and Medicines	0.25	2.50
	TOTAL	**100.00**	**1 006.74**

Table 3.5: Composition of starter ration S2 used for group TC

	INGREDIENT(As is)	%	MIX (kg)
1.	Yellow Maize 8.0 %	60.74	610.00
2.	Bran 15%	1.99	20.00
3.	Local Fish	4.98	50.00
4.	Soya Oil Cake 47%	24.40	245.00
5.	Sunflower Oil Cake 38%	4.98	50.00
6.	Lysine HCL	0.11	1.11
7.	DL Methionine	0.17	1.74
8.	L Threonine	0.09	0.89
9.	Monocalcium phos	0.80	8.00
10.	Limestone	1.39	14.00
11.	**Salt**	**0. 10**	**1.00**
12.	Vitamins and Medicines*	0.25	2.50
	TOTAL	**100.00**	**1 004.24**

* The medicines in Tables 3.4. and 3.5 consisted of 60 parts per million of Salinomycin and 3 parts per million of Flavomycin.

3.3.2.3 Calculated nutritive value of rations used

The calculated nutritive value of TA, TB and TC rations are given in Tables 3.6, 3.7 and 3.8 respectively.

Table 3.6: Calculated nutritive value of the grower ration used in group TA

NUTRIENT	AS IS
Moisture (%)	10.00
Protein (%)	19.00
D lysine (%)	1.05
ME MJ/kg	12.70
Fat (%)	3.98
Fibre (%)	5.87
Calcium (%)	0.90
Phosphorous (%)	0.73
Available phosphorous (%)	0.42
Sodium (%)	0.17

Table 3.7: Calculated nutritive value of starter ration S1 used in group TB

NUTRIENT		MINIMUM	AS IS
ME Poultry	MJ/kg	12.50	12.48
Crude Protein	g/kg	220.00	220.31
Lysine	g/kg	0.00	12.81
T.S.A.A.*	g/kg	0.00	9.22
Tryptophan	g/kg	0.00	2.58
Fat	g/kg	0.00	35.41
Fibre	g/kg	0.00	36.02
Calcium	g/kg	10.00	10.24
Total phosphorus	g/kg	6.50	6.94
Available phosphorus	g/kg	4.50	4.47
Sodium	**g/kg**	**2.00**	**1.95**
Xanthophyll	mg/kg	0.00	12.12
Available P (New)	g/kg	0.00	2.32
AP Lysine	g/kg	11.44	11.47
AP Methionine	g/kg	5.03	5.42
AP TSAA*	g/kg	8.24	8.23
AP Isoleusine	g/kg	7.44	8.74
AP Tryptophan	g/kg	1.83	2.21
AP Theorine	g/kg	7.32	7.34
AP Arginine	g/kg	8.47	13.38

TSAA * : Total sulfur amino acids

Table 3.8: Calculated nutritive value of starter ration S2 used in group TC

NUTRIENT		MINIMUM	AS IS
ME Poultry	MJ/kg	12.50	12.50
Crude Protein	g/kg	220.00	219.27
Lysine	g/kg	0.00	12.74
T.S.A.A.*	g/kg	0.00	9.20
Tryptophan	g/kg	0.00	2.57
Fat	g/kg	0.00	35.60
Fibre	g/kg	0.00	36.41
Calcium	g/kg	10.00	10.26
Total phosphorus	g/kg	6.50	6.97
Available phosphorus	g/kg	4.50	4.48
Sodium	**g/kg**	**1.00**	**1.01**
Xanthophyll	mg/kg	0.00	12.15
Available P (New)	g/kg	0.00	2.33
AP Lysine	g/kg	11.44	11.40
AP Methionine	g/kg	5.03	5.41
AP TSAA	g/kg	8.24	8.21
AP Isoleusine	g/kg	7.44	8.68
AP Tryptophan	g/kg	1.83	2.19
AP Theorine	g/kg	7.32	7.31
AP Arginine	g/kg	8.47	13.38

TSAA* Total sulfur amino acids

The grower ration was bought from a South African feed company (Meadow Feeds, Gauteng) whereas the starter ration (S1 and S2) were mixed at Irene Agricultural Research Institute. Bread used to make DBP was bought from Boerstra Bakeries.

3.3.2.4 Measuring and recording other variables

Maximum and minimum temperature, mortality and observation of clinical signs and behaviour were recorded on a daily basis. Body weight (kg), weight gain (kg), feed consumption (kg), cumulative feed consumption (kg), feed conversion and cumulative feed conversion were calculated and recorded on a weekly basis. The scale used for weighing birds and feed (kg) was a calibrated electronic scale, corrected to three decimal points (Richter scale, model KA-10). The price of different treatment diets was recorded when feed was purchased . Results of feed analysis were recorded depending on the size of the batch of DBP and commercial feed received. Records were placed in a permanent file and entered in the computer on a weekly basis.

3.4 Observation /Analytical procedures

Farming, as it becomes more and more business orientated, becomes also more complex financially and technically. Greater demands are made on the financial and technical abilities of the farmer. For this reasons our observation and analytical procedure was divided into two sections: economic efficiency and technical efficiency.

3.4.1 Economic efficiency

The following basic economic analysis will be done to determine the cost effectiveness of substituting DBP for maize according to the economics of commercial production (Buckett, 1988; Casavant, 1999; Heady, 1965; Penson, 2002):

- Cost analysis of the three treatment groups (TA, TB and TC).
- Production functions: relationships between total physical, average physical and marginal physical product.
- Least cost combination and substitution ratio.
- Gross margin analysis including a feed cost analysis and its impact on the total production cost.

Scenario planning will be done substituting current input and output costs and comparing them to costs at the time of the trial. Extension messages will be formulated for small-scale broiler production based on these analyses.

3.4.1.1 Definitions

Resource, input, and factor are all used to denote the goods utilised in the production process. The letter “X” usually denotes these. Production, output and product are denoted by the letter “Y” and are the goals or end result of the production process (Casavant, 1999; Penson, 2002).

For the purpose of our experiment, resource, input, and factor will be DBP and broiler starter ration (kg), consumed at different time intervals during the trial. Production, output and product will be measured as the live weight of the birds (kg) at different time intervals during the trial

- **Total physical product (TPP)** is simply the amount of output (live-weight of chicken) brought about by each level of input (DBP and broiler starter ration). It is usually designated TPP or TP in most economic analyses (Buckett, 1988; Casavant, 1999; Penson, 2002).

- **Average physical product (APP)** is the output at each level divided by that level of input. It is derived notationally by Y/X and is designated as APP. It indicates the average productivity of the inputs being used. Y will have different values for each group: TA, TB and TC (Casavant, 1999; Penson, 2002). The research question will then be whether Y is significantly different between groups TA, TB and TC and whether the ratio (APP) between groups is significantly different.

- **Marginal physical product (MPP)** is the amount of additional product obtained for a given increase in a given increase in input usage and is usually designated as MPP. Marginal physical product is computed by $\Delta Y/\Delta X$ where the symbol delta means “change in “. So this formula illustrates how much additional (marginal) output we received for an additional (marginal) unit of input (Casavant, 1999; Penson, 2002).

3.4.1.2 Relationships between TPP, APP and MPP.

The relationship between TPP, APP and MPP will help to determine the level of input and the corresponding output that would maximise profits (Casavant, 1999).

3.4.1.3 Gross margin analysis

The gross margin for each farm enterprise is the difference between the income (value of output) and the direct (variable) costs associated with the enterprise. The gross margin represents the contribution of the enterprise towards paying the fixed (overhead) costs of the farm. The total (sum) of the gross margins of the various farm enterprises minus the fixed (overhead) costs of the farm gives the net profit (Buckett, 1988).

3.4.2 Technical efficiency

3.4.2.1 Feed intake

The weekly and cumulative feed intake was calculated in kg. The feed was weighed every Monday morning starting at 08:00, using a calibrated electronic scale.

i. <u>Weekly feed intake</u>

The weekly feed intake is the amount of feed eaten per group over a seven-day period, less residual feed. The following calculations can be done at this stage:

- Feed intake per replicate: amount of feed consumed per group of 38 birds over a seven-day period, less the leftovers.
- Average feed intake per bird per replicate: feed intake per replicate divided by the number of birds in a replicate.
- Feed intake per treatment per week: total amount of feed consumed by all the replicates (five replicates for each treatment) over a period of seven days.
- Average feed intake per bird per treatment per week: feed intake per treatment per week divided by the number of birds per treatment.

ii. Cumulative feed intake:

The cumulative feed intake was calculated as the sum of weekly feed intake at the end of a phase, e.g. 7, 21 and 42 days. The cumulative feed intake was calculated and recorded on a weekly basis.

Data recorded was used to:

- Indicate the amount of feed consumed over the first seven days
- Determine the amount of feed consumed at the end of each feeding phase (21, 35 and 42 days) per replicate or per treatment.
- Determine the ratio of DBP to broiler starter ration consumed by treatment groups TB and TC at the end of each feeding phase.
- Determine the cost of the feed consumed per live bird, per kg of live bird as well as per treatment (TA, TB and TC), at the end of each feeding phase.

3.4.2.2 Body weight

All the birds were individually weighed on Days 7, 14, 21, 28, 35 and 42 .

Data obtained were used to determine:

- The average body weight/replicate/week (kg).
- The average body weight/treatment/week (kg).
- The average body weight/bird/treatment at 42 days (kg).

3.4.2.3 Feed conversion

Feed conversion indicates how efficiently the feed can be converted into protein (meat). Feed conversion was calculated at the end of the experiment, using the following formulas:

1. $$\frac{\text{Total feed consumed in kg at 42 days}}{\text{Body weight in kg at 42 days}}$$

(North, 1990a; Noktula, 2000).

2. $$\frac{\text{Total feed consumed in kg at 42 days}}{\text{Body weight (kg) 42 days – initial body weight (body weight at Day 1)}}$$

(Le Roux, 2000)

The feed intake and body weight were measured in kg, using a calibrated electronic scale, accurate to three decimal points (Richter scale, model KA-10).

3.4.2.4 Temperature

Maximum and minimum temperatures were recorded in degrees (Celsius) on a daily basis using a minimum and maximum thermometer, accurate to one decimal point, placed in the broiler house. Temperature was recorded every day at 08:00.

3.4.2.5 Processing of bakery waste

Bakery waste (brown and white bread) was obtained on a weekly basis for a period of 15 weeks from a local bakery in Pretoria West (Boerstra Bakery). Each batch contained 100 loaves of white and brown bread. Loaves and slices were broken into small pieces, this allowed for adequate drying. About 50 pieces of each batch were weighed to determine the average weight of each piece (approximately 63 g). These pieces and bread slices were placed on the cemented floor of one of the chicken houses (open sided house) at Onderstepoort to enable the bread to dry under the heat of the sun and wind penetrating through the openings of the house. Bread was visually inspected for mould on delivery and any loaf showing evidence of mould, was discarded.

The bread was allowed to dry to an estimated moisture content of less than 10%. To achieve this, the bread was appraised by visual means and tested for its breakability. Pre-trials have indicated that the drying process takes at least a week regardless of the time of the year. The bread was then milled using a hammer mill to produce mash and weighed using a calibrated scale available at the poultry unit.

3.4.2.6 Records:

Results of all feed analysis of bread and experimental feeds were kept in a file, as well as on a computer file.

i. <u>Nutrient composition analysis</u>:

The following analysis of feed samples (one kg) were performed at the University of Pretoria Nutrition Laboratory in the Department of Animal and Wildlife Sciences for each diet group, TA, TB and TC, as well as DBP.

Analysis of crude protein, fibre (total), calcium, sodium, fat, phosphorous dry matter and moisture were performed using the AOAC International official methods of analysis, as described by Horwitz (2000). The energy was calculated using the "modular calorimeter" model (MC-1000)

The parameters analysed are shown below.

Dry matter:	%
Moisture	%
Crude protein CP (NX, 25) :	%
Crude fibre: Total:	%
Calcium Ca:	%
Sodium Na:	ppm
Gross energy:	MJ ME/ Kg.
Fat	%
Phosphorous	%
Ash	%.

ii. Mycotoxin tests:

A sample of 1 kg of DBP was sent to the ARC-Onderstepoort Veterinary Institute Laboratory for a Rapid on-site screening test for aflatoxin since as it is the most important mycotoxin in poultry rations and could have been a problem in DBP. As it was negative, it was presumed that the DBP, which was essentially a product produced for human consumption and visually free from fungal growth, was likely to be safe. Although more rigorous testing would have been preferred, the tests are expensive and there were financial constraints.

iii. Prices of different diets:

The DBP was free of charge and the prices of the two commercial starter rations used in TB and TC (S1 and S2), as well as the commercial grower ration used in TA, were recorded.

3.4.2.7 Mortalities

Dead birds were necropsied at the Veterinary Faculty poultry laboratory and post-mortem reports recorded. Percentage mortalities for each diet were calculated and data from groups TA, TB and TC were compared statistically.

3.4.2.8 Stocking density

The stocking density is calculated as the floor space provided per bird, or the number of birds per square (sq) meter floor space. Stocking density is determined by the final live weight. In this experiment the stocking density was calculated according to the standards for environmentally controlled housing, i.e. 21 adult birds per sq meter (34 kg live-weight /sq m). (North, 1990a).

3.4.2.9 Data analysis and statistics

Data was recorded using the Microsoft Excel® spreadsheet on SAS (statistic analysis system) package and the significance of differences between TA, TB and TC were calculated using analysis of variance (ANOVA). The confidence interval was taken at the 95% level (P= 0.05) assuming a body weight range between 1.9 and 2.5 kg per broiler at 42 days, with a common standard deviation of 0.28 kg (based on previous similar trials in the same facility).For a power of 90% and sample sizes of 176 and 200 per group; an effect of 0.156 kg and 0.146 kg respectively, would be considered significant at a confidence interval of 95% (p = 0.05). This resulted in little differences in weight of birds, as an effect of 0.10 kg was regarded as small, 0.25 kg as medium and 0.4 kg as large. Accurate weighing of birds was therefore very important. A sample size of 190 birds per group was taken and the effect decreased to 0.10, the power dropped to 58% (P <0.05), which was acceptable. Under the above assumption, a small difference between the three treatments was identified.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was undertaken to determine the economic implications of substituting DBP for maize, as well as performance of broilers in terms of feed intake, body weight, mortalities and feed efficiency under a choice feeding system. The nutrient value and the mycotoxin contamination of DBP were further determined.

As discussed in Chapter 2 (Literature Review), in most publications, selection from two foods presented using the CFM, is most likely to be on the basis of their protein or energy content (Holocombe *et al*., 1976a; Leeson & Summer, 1978; Brody *et al*., 1984; Emmerson *et al*., 1990; Emmerson *et al.*, 1991; Forbes & Shariatmadari, 1994). Calcium, phosphorus, zinc, salt (NaCl) and vitamins such as thiamine may also play a role in selection (Mongin & Sauveur, 1974; Holocombe *et al*., 1975; Holocombe *et al*., 1976b; Appleby, 1992).

This study was conducted during winter over a period of 42 days. Male broilers were used because of the variation that occurs in the growth and feed consumption of males and females. The housing, environment and management of the chicks obtained from the hatchery are described under Chapter 3 “Materials and Methods”.

The composition of all the diets mentioned in this section, are described in Chapter 3. All chicks were fed the same commercial mash diet for the first seven days and then two groups were fed choice diets. Broilers were assigned to three equal groups with different feeds: As previously described, they were groups TA (control), TB (choice feeding with DBP and starter ration with normal salt) and TC (choice feeding with DBP and starter ration low salt).

In commercial production, broiler chickens are normally fed a ration containing 22% of protein from 1 – 21 days (starter), 20% of protein from 22 - 35 days (grower) and 18% of protein from 36 - 42 days of age (finisher). In this experiment S1 and S2 (starter commercial rations) containing 22% of protein were given over the experimental period to groups TB and TC respectively. Starter ration S1 contained 0.35% of NaCl which is the normal salt content required for broiler chickens and is higher than the lower % of NaCl in S2 (0.10%). S1 was given to all three groups during the pre-experimental period and to group TA over the starter period.

4.1 Feed intake

Feed intake was used as a measure of broiler growing efficiency, and as a comparison with feed efficiency and growth.

4.1.1 Cumulative feed intake

4.1.1.1 Cumulative feed intake for TA, TB and TC (Raw data)

Table 4.1 shows the total cumulative feed intake (kg) per week and per treatment calculated from raw data. It is noted that TB and TC had a lower feed intake from day 14 - 42 than TA.

Table 4.1: Cumulative feed intake (kg) per treatment at various ages for TA, TB and TC

TIME (DAYS)	TA (Kg)	TB (Kg)	TC (Kg)
7	22.650	22.420	22.600
14	96.186	90.20	89.114
21	197.079	195.92	196.090
28	347.918	335.677	345.744
35	570.018	521.667	547.589
42	795.994	744.249	763.560

4.1.1.2 Average cumulative feed intake per bird for TA, TB and TC

Table 4.2 presents the mean and standard deviation of the average cumulative feed intake per bird of the control group A (TA), group B (TB) and group C (TC) for different ages in days. It may be noted that the intake varied between the groups. The standard deviations are very small, indicating that there was a small variation, as the majority of chicks in each group ate the same amount per day.

Over the first seven days all three groups (TA, TB and TC) had similar feed intakes measured as average feed intake per bird, in kg per week. There was no significant difference between the intakes of the three groups ($P > 0.05$).

The groups TB and TC were put on separate feeding from Day 7 (Table 4.2). The inclusion in the diet of DBP1 and DBP2 had a significant effect ($P < 0.05$) on the feed intake. It was found that the two experimental groups (TB and TC), had lower feed intakes per bird than those fed on TA at 14 days. However, there was no significant difference between TB and TC ($P > 0.05$).

Table 4.2: Mean and standard deviation of the cumulative feed intake (kg) per bird at various ages in groups TA,TB and TC

TIME (DAYS)	TA	TB	TC
7	0.119 ± 0.01	0.118 ± 0.01	0.119 ± 0.01
14	0.507 ± 0.02[a]	0.475 ± 0.01[b]	0.471 ± 0.02[b]
21	1.052 ± 0.02	1.056 ± 0.06	1.060 ± 0.05
28	1.877 ± 0.04	1.833 ± 0.09	1.887 ± 0.04
35	3.105 ± 0.08[a]	2.867 ± 0.11[b]	3.008 ± 0.05[a]
42	4.376 ± 0.11[a]	4.110 ± 0.12[b]	4.214 ± 0.05[b]

[a-b] Mean in a row for groups with no common superscript differ significantly ($P < 0.05$)

When the average cumulative feed intake was measured at 21 and 28 days, the birds in groups TB and TC were found to have eaten sufficient feed to almost equalise the feed intake of group TA. In other words, the average cumulative feed intake/bird of the three groups (TA, TB and TC) did not differ significantly ($P > 0.05$) when measured at 21 days and again at 28 days.

The cumulative proportion of feed voluntarily ingested by TA and TC was significantly higher ($P < 0.05$) than TB by day 35. TA and TC did not differ significantly ($P > 0.05$).

The average cumulative intake by day 42 is characterised by significantly higher ($P < 0.05$) feed intake for TA than TB and TC. TB and TC did not differ significantly ($P > 0.05$).

The general trend is seen in a histogram in Figure 4.1. It can be seen from the histogram that there was little difference in feed intake between groups TA, TB and TC until the end of week 4 (28 days). Over the last two weeks (day 28 – 42), the intake of feed by group TA was greater than that of group TB and TC.

The increase of feed intake by group TA might be related to the fact that the birds were given pelleted feed from 22 days, since broilers in South Africa are normally fed a pelleted grower ration from 21 - 42 days. The results of the present study agree with the experiments conducted by Nir *et al.,* 1990ab and Nir *et al.,* 1994 using coarse, medium, and fine mash. They stated that feed consumption increased and feed waste decreased with the increase in particle size. Reece *et al*., 1985, have also shown that broilers fed diets made from roller mill ground corn, having bigger particle size, performed better than broilers fed diets made from corn, ground with a hammer mill, having a smaller particle size.

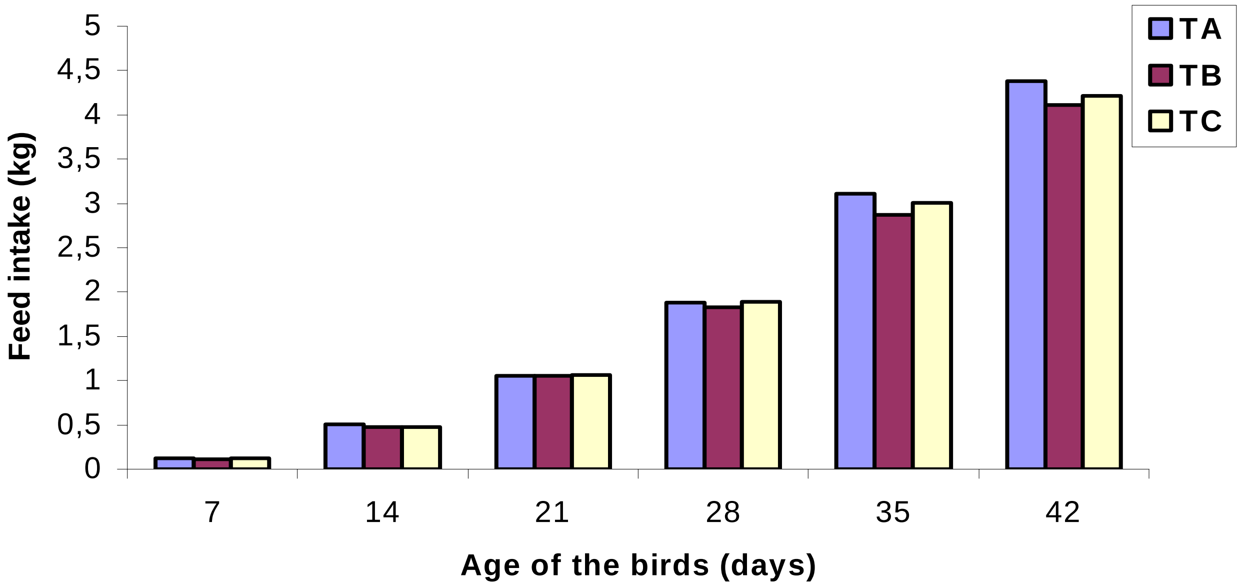

Figure 4.1 Average, cumulative feed intake (kg) per bird for groups TA, TB and TC over a 42- day period

The DBP has a higher salt content than starter and grower rations. Balog & Millar (1989), found that birds given flavoured diets with salt ate less of the diet than of the unflavoured. However, our results show (Table 4.2, Fig 4.1) that the effect of salt on the overall feed intake was not significant. The birds observed during the experiment did not show any sign of toxicity caused by the higher level of salt in the DBP given on the CFM. Signs of salt intoxication include inability to stand, intense thirst, pronounced muscular weakness, and convulsion movements preceding death (Austic & Scott, 1997).

4.1.1.3 Cumulative feed intake for S1, S2, DBP1 and DBP2 (Raw data)

The cumulative feed intake of the different ingredients used in the CFM for groups TB and TC, i.e. S1, S2, DBP1 and DBP2, is shown in Table 4.3

Table 4.3: Cumulative feed intake (kg) at various ages, per ingredient (S1, S2, DBP1 and DBP2) in groups TB and TC

TIME	TB		TC	
(DAYS)	S1 (Kg)	DBP1 (Kg)	S2 (Kg)	DBP2 (Kg)
7	22.420	0.000	22.600	0.000
14	74.350	15.850	74.384	14.730
21	143.656	52.264	144.103	51.989
28	231.623	104.054	233.061	112.685
35	354.625	167.042	355.589	192.002
42	510.121	234.128	516.099	247.463

4.1.1.4 Average cumulative feed intake per bird per week: proportion of S1, S2, DBP1 and DBP2 consumed

The cumulative feed intake (kg/bird) of S1 and S2, DBP1 and DBP2 were compared separately to show the influence of a NaCl concentration on different diets, since it was the target of free choice.

Table 4.4 shows the mean and standard deviation of weekly data for cumulative intake (kg/bird) of S1, S2 and of DBP1 and DBP2. General trends for cumulative intake (kg/bird) are shown as histograms in Figures 4.2 and 4.3.

Table 4.4: Mean and standard deviation of the cumulative feed intake (kg) per bird for S1, S2, DBP1 and DBP2

TIME	TB		TC	
(DAYS)	S1 (Kg)	DBP1 (Kg)	S2 (Kg)	DBP2 (Kg)
7	0.118 ± 0.01	0.000	0.119 ± 0.06	0.000
14	0.392 ± 0.01	0.084 ± 0.01	0.393 ± 0.01	0.078 ± 0.01
21	0.773 ± 0.03	0.284 ± 0.06	0.777 ± 0.02	0.284 ± 0.05
28	1.261 ± 0.05	0.572 ± 0.09	1.268 ± 0.04	0.619 ± 0.04
35	1.945 ± 0.05	0.923 ± 0.13^{a}	1.949 ± 0.08	1.060 ± 0.06^{b}
42	2.813 ± 0.08	1.298 ± 0.15	2.845 ± 0.07	1.370 ± 0.05

$^{a-b}$ Mean in a row for groups with no common superscript differ significantly ($P < 0.05$)

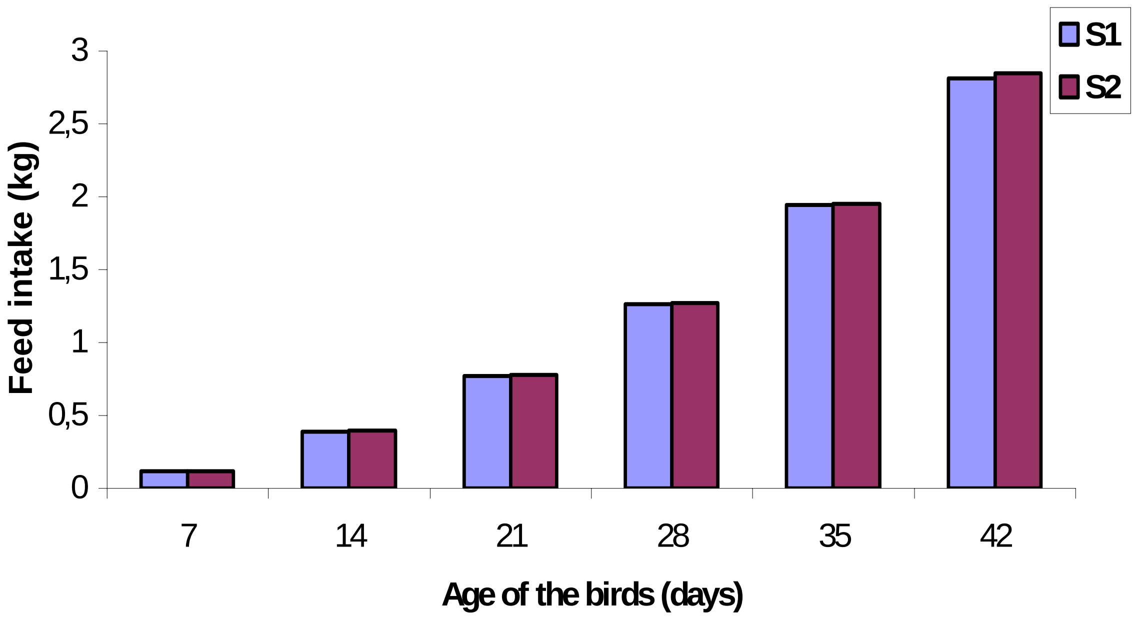

Figure 4.2: Average, cumulative feed intake (kg) per bird for diets S1 and S2 over a 42-day period

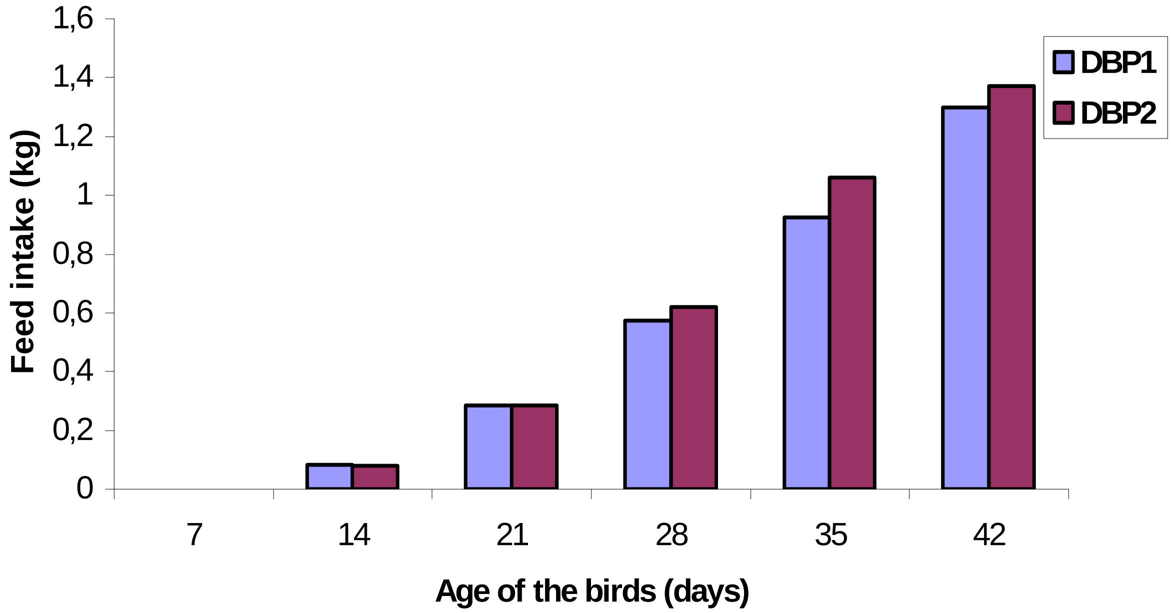

Figure 4.3 Average, cumulative feed intake (kg) per bird for DBP1 and DBP2 over a 42-day period

The NaCl content of the diet did not appear affect the intake of S1 and S2. No significant difference was observed throughout the experiment regarding the feed intake of birds between S1 and S2 (P >0.05). See Table 4.4 and Figure 4.2.

From Table 4.4 and Figure 4.3 it may be seen that group TC (DBP2) had a higher intake of DBP than group TB (DBP1). The difference was, however, not significant, it may have been influenced by the salt content of S1 and S2. S2 had a low salt content and the birds may have selected slowly more DBP in the diet to compensate.

4.1.2 Weekly feed intake

In contrast to the previous section where the parameter investigated and compared was the cumulative feed intake, this section will compare the amount of feed (kg) consumed per seven days.

4.1.2.1 Weekly feed intake for TA, TB and TC (Raw data)

The weekly feed intake per treatment (kg) is shown in Table 4.5.

Table 4.5: Weekly feed intake (kg) per treatment for TA, TB and TC

TIME (DAYS)	TA (Kg)	TB (Kg)	TC (Kg)
7	22.650	22.420	22.600
14	73.536	67.780	66.514
21	100.893	105.720	106.978
28	150.839	139.757	149.654
35	222.100	185.990	201.845
42	225.976	222.582	215.971

4.1.2.2 Average weekly feed intake for TA, TB and TC

Weekly feed intake of birds in groups TA, TB and TC were calculated to show the rate at which the birds on choice feeding systems (TB and TC) consumed their feed compared to the control (TA). A comparison was also made between S1 and S2, as well as DBP1 and DBP2.

In general, the average feed intake per week differed significantly (P <0.05) between groups (TA, TB and TC) as reflected in Table 4.6 and Figure 4.4. No significant difference was observed by day 7. This would be expected as all three groups had the same diet.

Table 4.6: Mean and standard deviation of the weekly feed intake (kg) per bird for groups TA, TB and TC.

TIME (DAYS)	TA (Kg)	TB (Kg)	TC (Kg)
7	0.120 ± 0.01	0.118 ± 0.01	0.119 ± 0.06
14	0.388 ± 0.01[a]	0.357 ± 0.01[b]	0.353 ± 0.02[b]
21	0.546 ± 0.00	0.581 ± 0.05	0.589 ± 0.05
28	0.826 ± 0.03[a]	0.777 ± 0.03[b]	0.827 ± 0.04[a]
35	1.228 ± 0.04[a]	1.034 ± 0.04[b]	1.222 ± 0.04[c]
42	1.272 ± 0.05[a]	1.244 ± 0.03[a b]	1.207 ± 0.03[b]

[a-c] Mean in a row for groups with no common superscript differ significantly (P <0.05)

Average feed intake per week/bird from 7 - 14 days, was significantly higher (P <0.05) for group TA compared to groups TB and TC, whereas groups TA and TC showed no significant difference (P >0.05). No significant difference was observed on Day 21 between the three treatment groups (P >0.05). From 21 - 28 days, groups TA and TC were higher than TB (P <0.05)

From 28 - 35 days, there was a significant difference (P <0.05) between the groups, TA was higher than TB and TC. TB had the lowest feed intake. Between 35 and 42 days, TA was significantly higher than TC (P <0.05), but no significant difference was observed between TA and TB and groups TB and TC (P >0.05).

The results show that each week the birds in all treatments ate more feed than they did the previous week, but this increase was not uniform, it varied from one group to the next and from one week to the next.

These results are similar to that of Emmans (1975), Hughes (1984), as well as Bradford & Gous, (1991a), who stated that animals have different dietary requirements for maintenance on the one hand and growth or production on the other. Animals with different levels of production might then be expected to select the two diets in a ratio appropriate to their needs.

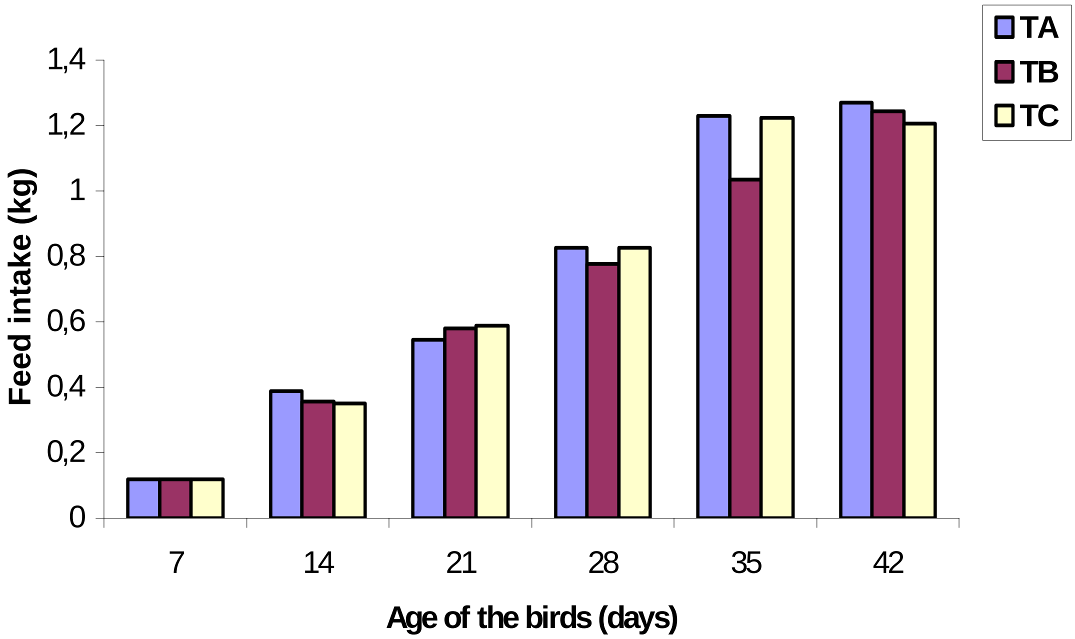

Figure 4.4 Average, weekly feed intake (kg) per bird for groups TA,TB and TC over a 42 day period

4.1.2.3 Weekly feed intake for feeds S1, S2, DBP1 and DBP2 (Raw data)

The weekly feed intake for S1, S2, DBP1 and DBP2 is given in Table 4.7.

Table 4.7 Weekly feed intake (kg) per treatment for diets S1, S2, DBP1 and DBP2

TIME (DAYS)	TB		TC	
	S1(Kg)	**DBP1(Kg)**	**S2(Kg)**	**DBP2(Kg)**
7	22.420	0.000	22.600	0.000
14	51.930	15.850	51.784	14.730
21	69.306	36.414	69.719	37.259
28	87.967	51.790	88.958	60.696
35	123.002	62.988	122.528	79.317
42	155.496	67.086	160.510	55.461

4.1.2.4 Average weekly feed intake S1, S2, DBP1 & DBP2

No significant difference was observed regarding the average feed consumption of S1 and S2 throughout this experiment (P <0.05), whereas, consumption for DBP1 and DBP2 was similar from 7 - 21 days (P >0.05).

However it was significantly different from 28 - 42 days (P <0.05). DBP1 was higher than DBP2 from 21 - 35 days but lower between 35 and 42 days. Feed gain and standard deviation are shown in Table 4.8, Figure 4.5 and Figure 4.6.

Table 4 8: Weekly feed intake (kg) per birds for feeds S1,S2, DBP1 and DBP2

TIME (DAYS)	**TB**		**TC**	
	S1	**DBP1**	**S2**	**DBP2**
7	0.118 ± 0.01	0.000	0.119 ± 0.01	0.000
14	0.274 ± 0.01^{b}	0.084 ± 0.01^{c}	0.275 ± 0.01^{b}	0.079 ± 0.01^{c}
21	0.381 ± 0.03^{b}	0.202 ± 0.06^{c}	0.384 ± 0.01^{b}	0.206 ± 0.05^{c}
28	0.489 ± 0.02^{b}	0.288 ± 0.03^{c}	0.492 ± 0.04^{b}	$0.336 \pm .020^{d}$
35	0.684 ± 0.03^{b}	0.351 ± 0.60^{c}	0.681 ± 0.05^{b}	0.441 ± 0.02^{d}
42	0.869 ± 0.05^{b}	0.375 ± 0.04^{c}	0.897 ± 0.03^{b}	0.310 ± 0.03^{d}

$^{a\text{-}b}$ Mean in a row for S1 and S2 with no common superscript differ significantly (P <0.05)

$^{c\text{-}d}$ Mean in a row for DBP1 and DBP2 with no common superscript differ significantly (P <0.05)

S1 and S2 were the balanced commercial diets, the only difference being levels of salt (NaCl). It may be seen from Table 4.8, Figure 4.5 and Figure 4.6 that there was no significant difference in the weekly intake of S1 and S2.

It appears that the DBP1 and DBP2 were used as supplements to satisfy requirements at different growth stages and this extra amount of feed (DBP) consumed per week was not uniform. It is suggested that where a choice is offered between two feed types, the consumption (kg / bird / week) of the feed that is closer to optimum, is less variable.

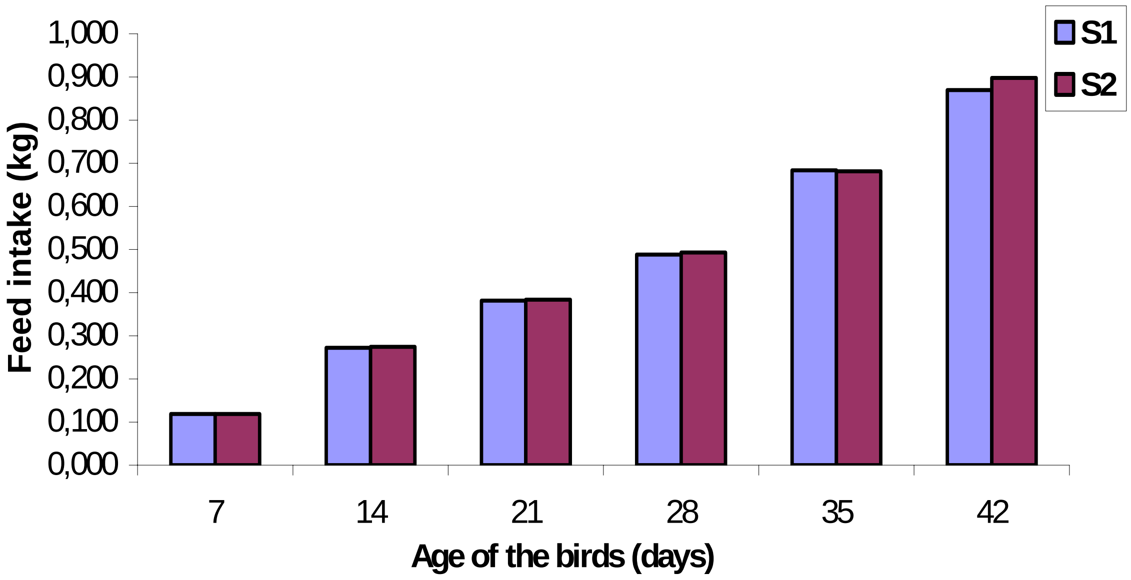

Figure 4.5 Average weekly feed intake per bird for diets S1 and S2

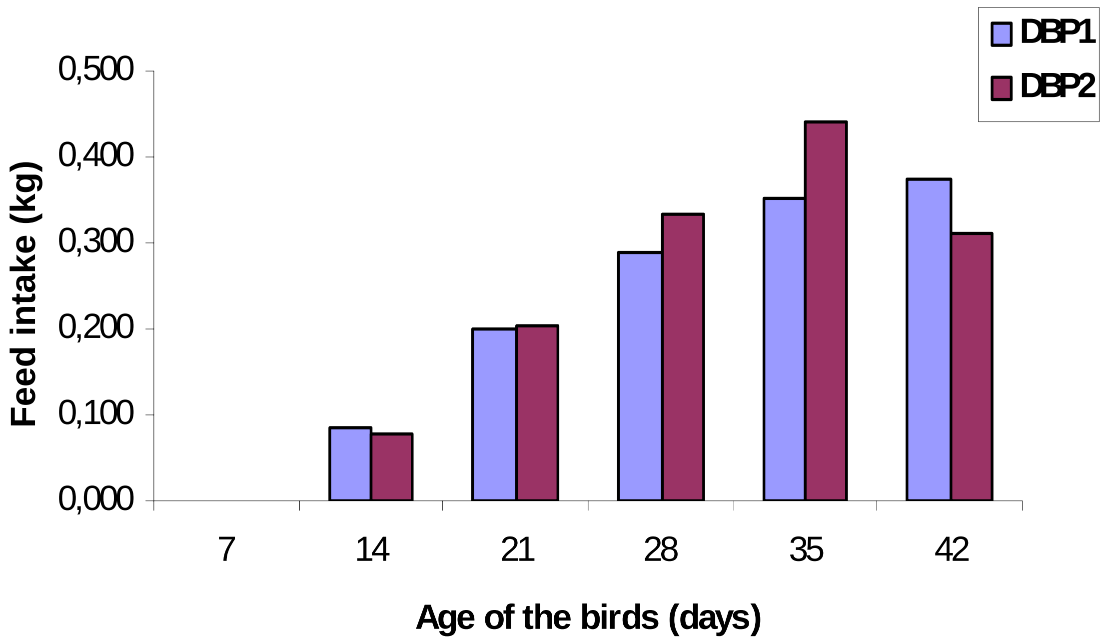

Figure 4.6 Average, weekly feed intake per bird for DBP1 and DBP2 over a 42 day period

4.1.3 Average cumulative and weekly percentage of DBP

The average cumulative percentage as well as the average weekly percentage of DBP1 and DBP2 as a proportion of total feed ingested were calculated and are shown in Table 4.9.

The cumulative proportion of DBP was calculated to show DBP as a percentage of total feed (DBP+S) ingested by groups TB and TC (kg/bird). The weekly proportion of DBP was calculated as percentage of total feed ingested per week (DBP + S) by group TB and TC (kg/bird/week). Please see Table 4.9 and Figures 4.7 and 4.8.

Table 4.9: Mean and standard deviation of DBP ingested (%) as a proportion of total feed consumed.

TIME (DAYS)	DBP1 (TB)		DBP2 (TC)	
	CUMULATIVE %	**WEEKLY %**	**CUMULATIVE %**	**WEEKLY %**
7	0.00	0.00	0.00	0.00
14	17.6 ± 1.68	23.4 ± 2.49	16.5 ± 2.39	22.0 ± 3.12
21	26.5 ± 4.68	34.1 ± 7.06	26.5 ± 3.30	34.6 ± 5.27
28	31.0 ± 3.62	37.1 ± 2.74	32.6 ± 2.01	40.6 ± 2.83
35	32.0 ± 3.40	33.8 ± 4 65^{a}	35.1 ± 2.04	39.5 ± 2.40^{b}
42	31.5 ± 2.90	30.2 ± 3.56^{a}	32.5 ± 1.25	25.7 ± 2.46^{b}

$^{a-b}$ Means within a row with no common superscript differ significantly (P <0.05).

4.1.3.1 Average cumulative % DBP as a proportion of (S1 + DBP1) in group TB and (S2 + DBP2) in group TC

No significant difference was observed between groups TB and TC regarding the cumulative DBP intake (P >0.05). As shown in Table 4.9 and in Figure 4.7 and Figure 4.8, there was a tendency to consume a higher proportion of the diets S1 and S2 than of DBP1 and DBP2, throughout the experiment.

As shown in Fig 4.7 and Fig 4.8, there was a general trend for DBP1 and DBP2 to increase at 14 and 21 days, to reach the maximum feed intake at 28 days and to decrease from day 35 and day 42.

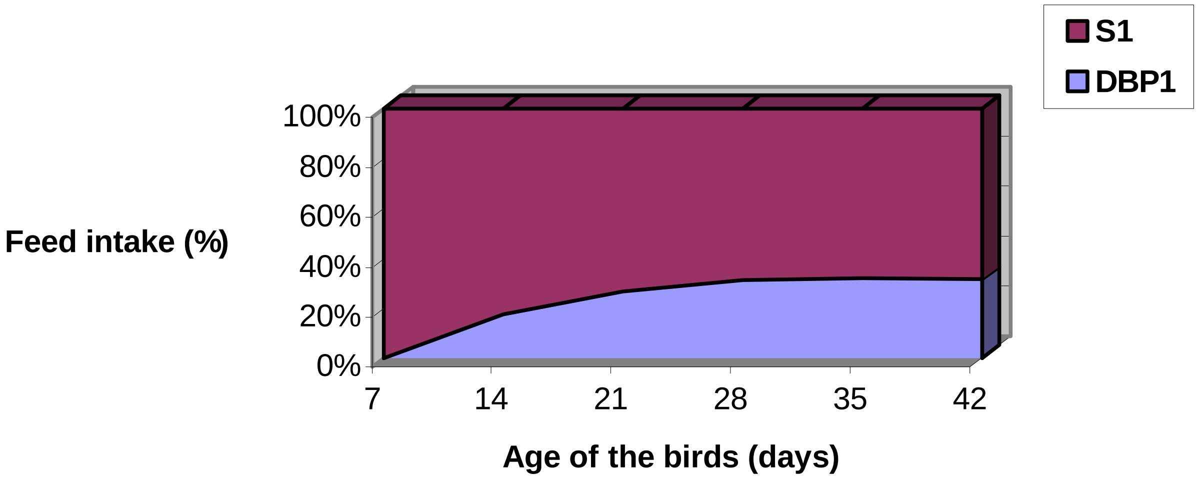

Figure 4.7 Average cumulative intake (%) per bird for DBP1 as a proportion of DBP1 + S1

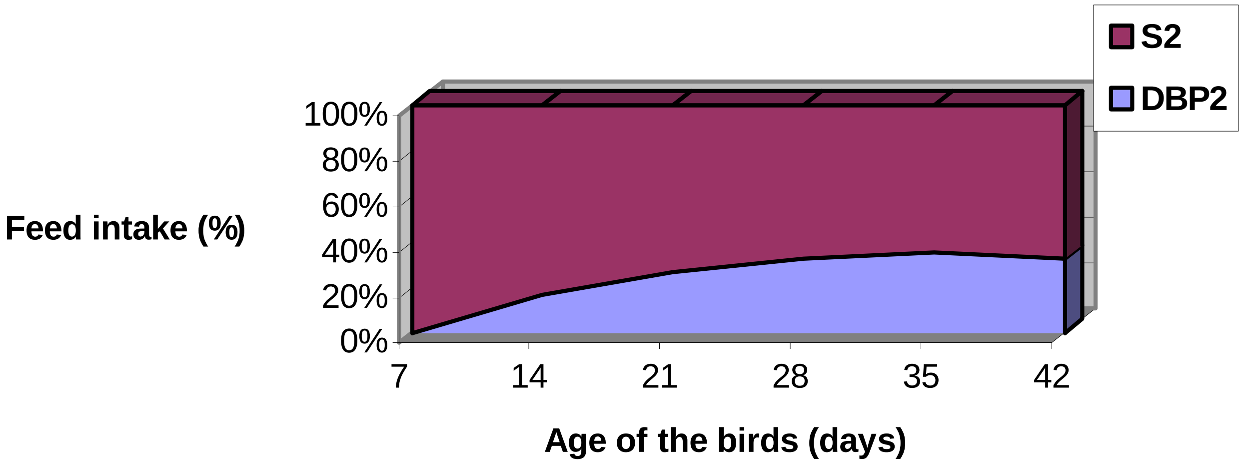

Figure 4.8 Average cumulative intake (%) per bird of DBP2 as a proportion of DBP2 + S2

In these experiments it was evident that the broilers markedly preferred the complete diets (S1 and S2) to DBP1 and DBP2 (Figure 4.7 and 4.8). Our results show that the birds exhibited preference for the diet close to optimum (S1 and S2) for their growth throughout the experiment, probably selecting the diet with the higher protein level.

This is in agreement with the study of Emmans (1978), who suggested that the feed intake in the choice situation depends on the nutrient requirements of the animal and feed composition, with little consideration for other factors

Factors such as sensory characteristics of diets (smell, taste, texture), which are unrelated to the nutrient composition, however, may have key roles in nutrient intake and regulation. When offered two foods, birds will select a diet which allows them to produce, as well as they would on the better food alone and will also avoid excess nutrient intake (Appleby, 1992)

In this experiment the birds were given a choice between a balanced (S1 and S2) and unbalanced diet (DBP1 and DBP2). Several experiments have shown that when given a choice between a balanced and an unbalanced diet the birds exhibit a marked preference for the balanced diet (Yo *et al*., 1998). When chickens were offered diets either above or below optimal protein content, they ate predominantly the diet closest to optimum (Shariatmadari & Forbes, 1993), as a result that agrees with the statement by Emmans (1977), that when formulations of two diets were such that no mixture of them was of adequate composition, then the animal would select in a way to minimise the inadequacy or excess. In nature or under practices conditions, chickens are, individually, incomplete and the challenge consists of evaluating all the feedstuffs present and selecting from them an adequate diet.

4.1.3.2 Average weekly % of DBP as a proportion of (S1 + DBP1) in group TB and (S2 +DBP2) in group TC

The weekly DBP % shows a significant difference between DBP1 and DBP2 ($P<0.05$) as measured at 35 and 42 with the highest intake at 28 days. Relatively high levels of DBP were consumed by the birds in our experiment, as shown in Figures 4.9 and 4.10. The maximum amount of DBP intake achieved on a weekly basis was 37.1% for TB and 40,6% for TC and the total amount of DBP at the end of the study was 31.5% for TB and 32.5% for TC.

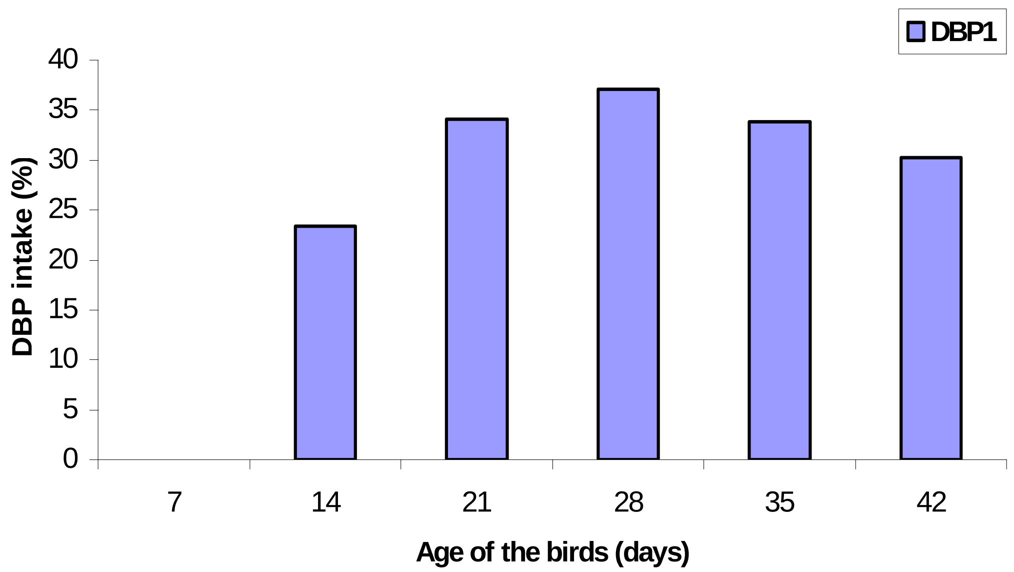

Figure 4.9 Average, weekly DBP1 intake (%) per bird for group TB

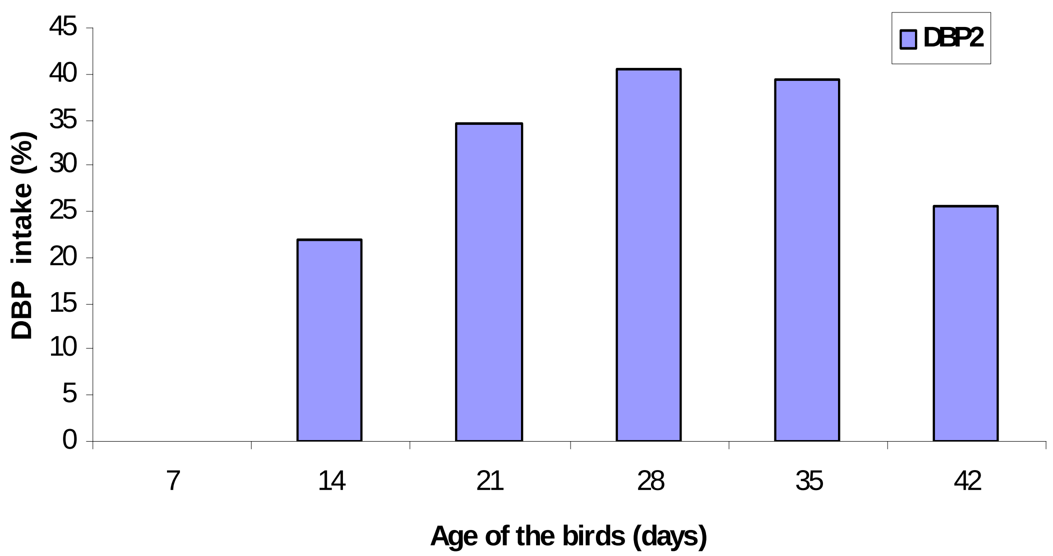

Figure 4.10 Average, weekly DBP2 intake (%) per bird for group TC

Compared to many other studies that have used DBP in their diets, the present experiment has used a greater proportion of DBP with no adverse effects on the birds. The maximum proportion of DBP used in the study of Damron *et al.*; (1965), as well as Harms *et al*, (1966) was 10%, Saleh *et al., (*1966) used 25% of the ration consisting of DBP, and Day *et al.,* (1968) used 15% as a maximum level of DBP.

The general trend in Fig 4.9 and Fig 4.10 shows an increasing proportion of DBP1 and DBP2 consumed up until 28 days and then the proportion slowly decreases. This suggests that there was a reduction in the requirements of birds for protein with time. Similar findings were also reported by Olver & Jonker (1997).

4.2 Growth performance

Growth performance was used as measure of broiler growing efficiency as a comparison with feed intake and Feed Conversion Rate (FCR).

4.2.1 Body weight per treatment (raw data)

Table 4.10 shows the weekly change of total body weight per treatment calculated from raw data. Chickens were weighed individually once a week and all the weights added together.

Table 4.10: Body weight (kg) per treatment for groups TA, TB and TC

VARIABLE	TA	TB	TC
Day		Body weight (kg)	
1	8.815	8.889	8.829
7	22.938	22.620	23.082
14	59.504	56.891	55.455
21	117.031	105.713	103.088
28	183.785	168.991	168.230
35	291.766	256.215	251.035
42	386.141	348.221	348.320

4.2.2 Average body weight per bird

Mean data related to growth of birds is presented in Table 4.11 and Figure 4.11. The body weight in kg of all the chicks on arrival was exactly the same for all groups. Although similar to those of the TA in the first 14 days (P >0.05), the mean body weight (kg) of birds in groups TB and TC (choice groups given DBP), remained lower than those of group TA (the control), for the rest of the experiment (P<0.05). The birds in groups TB and TC showed no significant difference (P >0.05) between groups, in weight gain (kg) over time.

Table 4.11: Mean and standard deviation of body weight (kg) at different ages

VARIABLE	TA	TB	TC
Day		Body weight, kg	
1	0.047 ± 0.00	0.047 ± 0.00	0.047 ± 0.00
7	0.121 ± 0.01	0.120 ± 0.01	0.122 ± 0.02
14	0.314 ± 0.31	0.300 ± 0.04	0.294 ± 0.04
21	0.633 ± 0.08[a]	0.581 ± 0.07[b]	0.567 ± 0.07[b]
28	1.005 ± 0.01[a]	0.939 ± 0.12[b]	0.930 ± 0.12[b]
35	1.612 ± 0.19[a]	1.424 ± 0.18[b]	1.395 ± 0.19[b]
42	2.170 ± 0.21[a]	1.946 ± 0.26[b]	1.946 ± 0.24[b]

[a b] Means in the same row (TA, TB and TC) with no common superscript differ significantly (P <0.05)

The gain (kg) of groups TB and TC were similar to that of TA during first 14 days of age, there was, however, a decrease in feed consumption on day 14 for the birds in the groups TB and TC. Our results show that the inclusion of DBP did not affect the mass of the broilers at this specific age, but affected the feed intake. The lower feed intake during the first 14 days probably accounted for the lower growth observed in groups TB and TC from day 21. Consequently, this might have led to a decrease in intake of energy, protein, vitamins and minerals with a significant effect on growth.

This is in agreement with the study conducted by Moran (1980), who reported that decreasing energy-protein levels of the diet could also lower body weight. Leeson *et al.,* (1996) stated that the increased growth rate of the broiler chicken is achieved by a concomitant increase in feed intake. Broiler chickens have traditionally been fed relatively high-energy diets because in addition to promoting efficient feed utilisation it is also assumed that this type of diet maximises growth rate (Leeson *et al*., 1996)

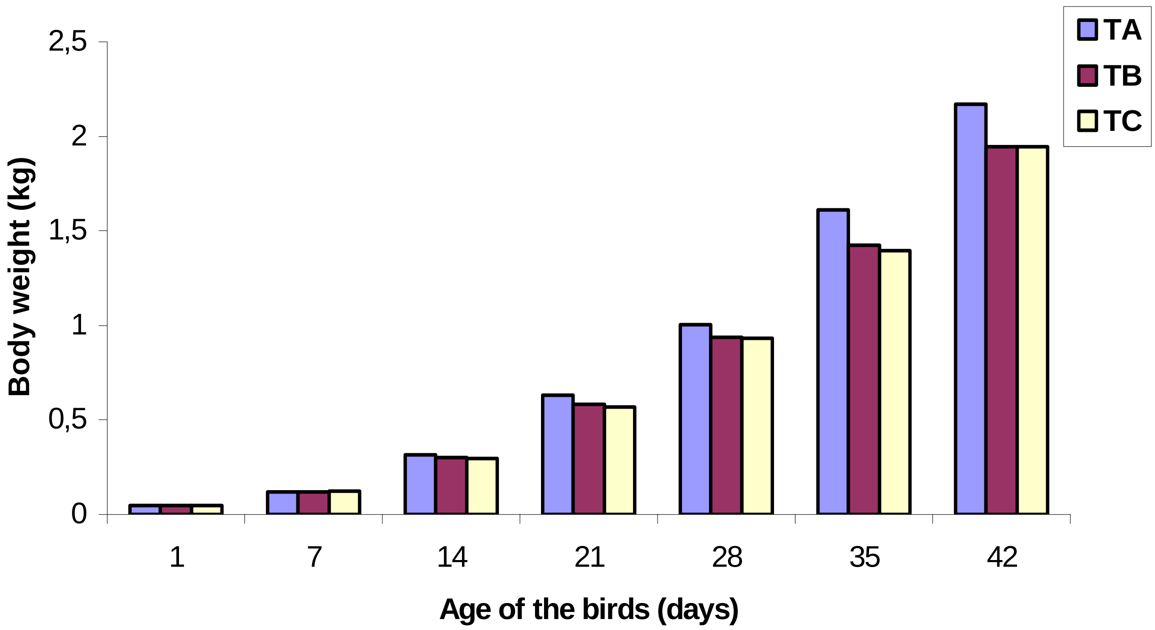

Figure 4.11 Average body weight (kg) for TA, TB and TC over a 42-day period

Although the cumulative feed intake of groups TB and TC became equal to that of the control (TA) on day 21 and day 28, the mean body weight of birds in groups TB and TC remained lower than those in TA. Presenting the control diet in pellet form from day 21 to group TA, induced a higher intake than the `diet given as mash to the groups TB and TC. The form of the feed may have been one of the reasons for increased intake and, therefore, increasing body weight in birds in group TA from day 21.

This is in agreement with the studies of Calet (1965); Proudfoot *et al*., (1982a); Proudfoot *et al*., (1982b); Reece *et al*., (1986), who found that feeding pellets resulted in a higher weight gain and more efficient broiler production. Several other feeding trials suggested that pelleting improved both growth and feed efficiency (Barley *et al*., 1968a; Barley *et al.,* 1968b; Schaible, 1976; Wilson & Nesbeth, 1980; Carre *et al*., 1987; Appleby, 1992; Plavnik *et al.*, 1997; Edwards *et al.*, 1999).

There was no significant difference in weight gains between groups TB and TC after the inclusion of DBP, despite the difference between the salt content of diets offered. At the end of the experiment (day 42), the birds in group TA were 0.224 kg or 10.3% heavier, on average, than the birds in groups TB and TC.

4.3 Feed conversion rate

Feed conversion rate can be calculated as:

1. Total feed intake (kg) over the duration of feeding divided by the total body weight measured in kg minus total initial body weight (kg) (Le Roux, 2000).

   Feed conversion rate calculated from formula 1:

   Means and standard deviation for the feed conversion rate over 42 days, were 2.75 ± 0.10, 2.75 ± 0.05 and 2.73 ± 0.;03 for groups TA, TB and TC respectively. No significant difference was observed at 42 days regarding the feed efficiency of groups TA, TB and TC (P>0.05).

2. In practice, FCR can also be calculated as the total feed intake (kg) divided by the total bodyweight at the end of production (kg) (North, 1990a; Noktula, 2000).

   FCR is a measure of feed efficiency (see Chapter 3).

   Feed conversion rate calculated from formula 2:
   Means and standard deviation for the feed conversion rate over 42 days were 2.06 ± 0.11; 2.14 ± 1.17; and 2,19 ± 0.06 for groups TA, TB and TC respectively. No significant difference was observed at 42 days regarding the feed efficiency of groups TA, TB and TC (P >0.05), although TA showed the lowest feed conversion rate of the three groups. This is an interesting finding because birds on diet TA had a higher feed intake (Figure 4.11) and higher weight gain (Table 4.11) than birds in TB and TC.

These results suggest that rations containing different levels of DBP are at least as efficient as TA in converting feed into live tissues in the form of meat. The use of DBP and different levels of salt in TB and TC did not affect the feed efficiency. Similar results were obtained by Daguro & Rivas (1987) and Eruvbetine & Afolami (1996), using cassava as an alternative energy feed source to maize.

4.4. Mortalities and necropsy results

The percentage mortality was calculated and necropsies were performed on all birds that died during the trial. Table 4.12 shows the mean and standard deviation of the mortality percentage, as well as necropsy results on birds from the three treatment groups (TA, TB and TC).

Percentage mortality was 6.32% for TA, 5.79% for TB and 5.79% for TC. There was no significant difference (P >0.05) between the three treatment groups

Table 4.12: Mortalities and Post-mortem results at 42 days for treatments TA, TB and TC.

TREATMENT GROUPS	TA	TB	TC
Number of mortalities	12/190	11/190	11/190
Mean and standard deviation of mortality percentage	6.32 ± 4.40	5.79 ± 1.18	5.79 ± 2.20
Post-mortem results or diagnosis	8 birds died of septicaemia 3 birds died of SDS 1 bird unknown	7 birds died of SDS 2 birds died of cold 2 birds were culled	All 11 birds died of septicaemia.

The percentage mortality of the three treatments groups (TA,TB and TC) is within the levels that would normally be expected on a efficient commercial poultry farm in South Africa, i.e. ≤ 6% (Le Roux, 2000). The fact that groups TA and TB show no significant differences, indicated that the different salt content between ration TB and TC did not appear to influence % mortality.

The necropsy results presented in Table 4.12 show that the birds died of septicaemia, sudden death syndrome (SDS) and cold. Some (n = 2) of the birds were culled. These conditions are commonly found in commercial poultry farms. Septicaemia is frequently caused by *E. coli* (Barnes & Gross, 1997). Sudden death syndrome (SDS) describes a condition in which healthy broiler chickens die suddenly for no discernible cause.

The syndrome has also been described as heart attack, and flip-over (Riddel, 1997). Most modern broiler chicken strains are susceptible. The experiment was conducted in winter and two birds died of cold, two others were underweight, also possibly due to cold and were culled.

4.5. Nutritive content of DBP

One of the objectives of this study was to evaluate the nutritive value of bread obtained from Boerstra Bakery and dried to 10% moisture.

4.5.1 Composition of DBP

Table 4.13 shows the composition of DBP collected from Boerstra Bakery. These results should be compared to those of Saleh *et al*., 1996, shown in Chapter 2. Amino acid analysis was not done in our experiment, due to cost constraints.

Table 4.13: Composition of DBP

NUTRIENT	AS IS "BASIS"	DRY MATTER "BASIS"
Dry matter %	90.40	100.00
Moisture %	9.60	0.00
Ash %	2.70	2.90
Gross energy MJ/kg	16.10	16.10
Crude protein %	12.70	14.10
Crude fibre %	0.50	0.50
Fat %	1.10	1.20
Calcium %	0.09	0.10
Phosphorus %	0.13	0.14
Na (mg /kg)	4 578.00	5 085.00

In the study conducted by Saleh *et al*., (1996) the sodium content was almost double (0.93%) that shown in Table 4.13 (0.51%). Crude fibre, calcium, phosphorous and ash were also higher in the DBP used in the study of Saleh *et al*., (1996). The other nutrients (crude protein, moisture and energy) had approximately the same percentage.

4.5.2 Analysis for mycotoxins

A definitive diagnosis of mycotoxicosis involves isolation, identification, and quantification of specific toxins. This is usually difficult in modern poultry production, because of the rapid and voluminous use of feed and ingredients. Analyses for aflatoxin and zearalenone are readily available, but for other aflatoxins are less available (Hoerr, 1997).

Milled DBP was rapidly screened for aflatoxin with commercially available ELIZA tests, and found to be negative for aflatoxin.

4.6 Economic evaluation

The main objective of our studies was to determine the relative feed cost of raising broilers from 0 - 42 days using DBP and the CFM.

The following calculations were done using a spreadsheet and raw data:

- The cost analysis of each feed at each growth stage.
- Total costs, total revenue and net profits.
- TPP, TPA and MP calculations.
- Gross margin analysis and Scenario planning.

4.6.1 Cost analysis of different diets in groups TA, TB and TC

The feed prices for poultry rations have increased with time, as has the price of poultry meat The cost analysis of each feed according to the groups given choice of feed (TB and TC) compared to the control group on commercial feed only (TA) is given in Tables 4.14 (scenario at current prices) and 4.15 (scenario using prices at time of trial). Tables 4.14 and 4.15 also show that the cost of feed over the first 7 days was the same for all treatments because the birds were fed on the same diet.

By day 21 the cost/kg of the total cumulative feed intake for groups TB and TC was lower than for group TA due to the partial replacement of commercial ration by DBP. From Day 21 the birds on TA were given grower ration, while TB and TC received starter ration plus DBP (R = 0.00) from day seven.

Table 4.14: Cost of feed from day 1 - 42 for groups TA, TB and TC projected to current prices: time intervals are given to explain calculation of feed costs at different phases

TIME IN DAYS	TA	TB		TC	
		S1	DBP	S2	DBP
Day 0 – 7*					
Cumulative feed intake (kg)	22.65	22.42	0.00	22.60	0.00
Cost in R/kg	2.63	2.63	0.00	2.63	0.00
Day 0 – 21**					
Cumulative feed intake (kg)	197.08	143.66	52.26	144.10	51.99
Cost per kg	2.63	2.63	0.00	2.63	0.00
Total feed intake (kg)	**197.08**	**195.92**		**196.09**	
Cost per kg for feed (R)	**2.63**	**1.93**		**1.93**	
Day 22 - 42 days***					
Cumulative feed intake (kg)	598.92	366.47	181.84	371.10	195.47
Cost per kg	2.56	2.63	0.00	2.63	0.00
Total feed intake (kg)	**598.92**	**548.31**		**566.57**	
Cost per kg for feed (R)	**2.56**	**1.76**		**1.72**	
Day 0 – 42					
Cumulative feed intake (kg)	796.00	744.23		762.66	
Cost of feed /kg day (R)	**2.58**	**1.80**		**1.78**	
Total feed cost/live bird day 42 (R)					
Total kg liveweight of birds	386.14	348.22		348.32	
Total number of birds at day 42	178.00	179.00		179.00	
Feed cost /live bird by day 42 (R)	**11.53**	**7.50**		**7.57**	
Feed cost/kg liveweight by day 42	**5.31**	**3.85**		**3.89**	

* All birds consuming S1
** TA continued on S1, TB and TC given CFM
***TA given grower ration

The period from day 21 - 42 is characterised by an increase in DBP intake by TB and TC, resulting in a decrease in cost/kg of the total feed consumed compared to TA, which remained constant.

From Tables 4.14 and 4.15, it can be seen that there was very little variation between TB and TC in total feed consumed. In contrast, chickens on diet TA consumed more feed than those on TB or TC. By day 42, the price per kg, as well as the total cumulative feed intake was lower for both TB and for TC than for TA. The total cost of feed per live bird and per kg liveweight, for group TB and TC, was lower than for group TA. It may be seen from the above that feed production costs using DBP and starter ration from day 7 (TB and TC) were lower than those using grower ration from day 22 (TA). This is mainly due to reduced feed consumption by groups B and C.

The feed intake results shown in Tables 4.14 and 4.15, also shows that salt concentration had no significant impact on feed choice by the birds. The fact that there is no significant difference between TB and TC in the consumption of either starter ration or DBP, indicates that the salt content did not play a role in diet choice by the birds. Had it done so, the birds in group TC would have consumed more of the S2 starter to compensate for the high salt level of the DBP. If the birds made a ration choice on the basis of higher salt, group TC would have consumed more DBP than group TB.

Table 4.15: Cost of feed from 1- 42 days for groups TA, TB and TC at time of trial-time intervals are given to explain calculation of costs at different phases

TIME IN DAYS	TA	TB		TC	
		S1	DBP	S2	DBP
Day 0 – 7*					
Starter (kg)	22.65	22.42	0.00	22.60	0.00
Cost in rand per kg	1.61	1.61		1.61	
Day 0 – 21**					
Cumulative feed intake (kg)	197.08	143.66	52.26	144.10	51.99
Cost per kg	1.61	1.61	0.00	1.61	0.00
Total feed intake (kg)	**197.08**	**195.92**		**196.09**	
Cost per kg for feed (R)	**1.61**	**1.18**		**1.18**	
Day 22 – 42***					
Cumulative feed intake(kg)	598.92	366.47	181.84	371.10	195.47
Cost per kg	1.56	1.61	0.00	1.61	0.00
Total feed intake (kg)	**598.92**	**548.31**		**566.57**	
Cost per kg for feed (R)	**1.56**	**1.08**		**1.05**	
Day 0 – 42					
Cumulative feed intake (kg)	796.00	744.23		762.66	
Cost of feed /kg day (R)	**1.57**	**1.10**		**1.09**	
Total feed cost/live bird day 42 (R)					
Total kg liveweight of birds	386.14	348.22		348.32	
Total number of birds at day 42	178.00	179.00		179.00	
Feed cost /live bird by day 42 (R)	**7.03**	**4.59**		**4.63**	
Feed cost/kg liveweight by day 42	**3.24**	**2.36**		**2.38**	

* All birds consuming S1

** TA continued on S1, TB and TC given CFM

***TA given grower ration

4.6.2 Total cost of production, total revenue and net profit for groups TA, TB and TC

The total input costs (fixed and variable), total revenue at time of trail and projected to current costs, as well as net profits at time of trail and projected to current costs (scenario 1 and scenario 2), are given in Tables 4.16, 4.17 and 4.18.

Table 4.16: Total production cost, total revenue and net profit for group TA

ITEMS	DESCRIPTION	UNIT	AMOUNT	CURRENT PRICES		PRICES AT TIME OF TRIAL	
				PRICE (R)	TOTAL (R)	PRICE (R)	TOTAL (R)
<u>Production costs</u>							
Fixed costs							
Broilers	DOC (male)*	Chicks	190	2.83	537.70	2.38	452.20
Total fixed costs					**537.70**		**452.20**
Variable costs							
Feed	Starter	Kg	197.08	2.63	518.32	1.61	317.30
	Grower (pellet)	Kg	598.92	2.56	1 533.24	1.56	934.32
Litter	Pine shavings	Bags	2.60	9.00	23.40	8.00	20.80
Vaccination	Newcastle	Bottle	0.67	10.08	6.71	8.40	5.59
	Gumboro	Bottle	0.67	22.16	14.76	17.57	11.70
Sanitation	Vet One Plus	Litre	0.11	16.56	1.87	15.47	1.75
	GL 20	Litre	0.20	18.39	3.59	17.69	3.45
Slaughtering fee	Broiler	Live bird	178.00	2.00	356.00	1.20	213.60
Total variable costs					**2 457.88**		**1 508.51**
Total cost: fixed plus variable					**2 995.58**		**1 960.71**
<u>Total revenue</u>							
Revenue	Slaughter weight (kg)			Price (kg)		Price (kg)	
	270.299			15.00	**4 054.49**	8.75	**2 365.12**
<u>Net profit</u>							
Revenue less costs					**1 058.90**		**404.41**

Table 4.17 Total production cost, total revenue and net profit for group TB

ITEMS	DESCRIPTION	UNIT	AMOUNT	CURRENT PRICES		PRICES AT TIME OF TRIAL	
				PRICE (R)	TOTAL (R)	PRICE (R)	TOTAL (R)
Production costs							
Fixed costs							
Broilers	DOC (male)*	Chicks	190	2.83	537.70	2.38	452.20
Total fixed costs					**537.70**		**452.20**
Variable costs							
Feed	Starter	Kg	510.12	2.63	1 341.62	1.61	821.29
	DBP	Kg	234.11	0.00	0.00	0.00	0.00
Litter	Pine shavings	Bags	2.60	9.00	23.40	8.00	20.80
Vaccination	NewCastle	Bottle	0.67	10.08	6.71	8.40	5.59
	Gumboro	Bottle	0.67	22.16	14.76	17.57	11.70
Sanitation	Vet One Plus	Litre	0.11	16.56	1.87	15.47	1.75
	GL 20	Litre	0.20	18.39	3.59	17.69	3.45
Slaughtering fee	Broiler	Live bird	179.00	2.00	358.00	1.20	214.80
Total variable costs					**1 749.95**		**1 079.39**
Total cost: fixed plus variable					**2 287.65**		**1 531.59**
Total revenue							
Revenue	Slaughter weight (kg)			Price (kg)		Price (kg)	
	243.754			15.00	**3 656.31**	8.75	**2.132.85**
Net profit							
Revenue less costs					**1 368.66**		**601.26**

Table 4.18 Total production cost, Total revenue and net profit for group TC

ITEMS	DESCRIPTION	UNIT	AMOUNT	CURRENT PRICES		PRICES AT TIME OF TRIAL	
				PRICE (R)	TOTAL (R)	PRICE (R)	TOTAL (R)
Production costs							
Fixed costs							
Broilers	DOC (male)*	Chicks	190	2.83	537.70	2.38	452.20
Total fixed costs					**537.70**		**452.20**
Variable costs							
Feed	Starter	Kg	516.099	2.63	1 357.34	1.61	830.92
	DBP	Kg	247.463	0.00	0.00	0.00	0.00
Litter	Pine shavings	Bags	2.60	9.00	23.40	8.00	20.80
Vaccination	NewCastle	Bottle	0.67	10.08	6.71	8.40.	5.59
	Gumboro	Bottle	0.67	22.16	14.76	17.57	11.70
Sanitation	Vet One Plus	Litre	0.11	16.56	1.87	15.47	1.75
	GL 20	Litre	0.20	18.39	3.59	17.69	3.45
Slaughtering fee	Broiler	Live bird	179.00	2.00	358.00	1.20	214.80
Total variable costs					**1 765.67**		**1 089.01**
Total cost: fixed plus variable					**2 303.37**		**1 541.21**
Total revenue							
Revenue	Slaughter weight (kg)			Price (kg)		Price (kg)	
	243.824			15.00	**3 657.36**	8.75	**2 133.46**
Net profit							
Revenue less costs					**1 353.99**		**592.25**

Table 4.16 shows the total production cost, total revenue and net profit for group TA, with two scenarios: at the time of the trial and currently. Tables 4.17 and 4.18 show the total production cost, total revenue and net profit for groups TB and TC respectively, both at the time of the trial and currently.

In the context of this study the total revenue (TR) per group was defined as:

TR = (price per kg x total kg of live birds at 42 days x meat yield).

Average meat yield after slaughter was found to be 70%. Current price per kg chicken is R15.00, while the price per kg at the time of the trail was R8.75.

From Tables 4.16, 4.17 and 4.18, it can be seen that both TB and TC showed a reduction on the total cost of production compared to TA.

Variable costs were also reduced for TB and TC compared to TA. There was also a higher profit for TB and TC, than for TA, despite the fact that the total weight of birds in TA was higher than those of the other two groups.

In both situations (at current price and price during the trial) the use of DBP resulted in a reduction of the total cost of production, total variable cost and in a higher profit in both TB and TC compared to TA .

Table 4.19: Total production cost and net profit per live bird, per kg of live weight and per kg of meat in Rand

	TA		TB		TC	
	NOW	**THEN**	**NOW**	**THEN**	**NOW**	**THEN**
Total cost/live bird	16.83	11.01	12.78	8.56	12.87	8.61
Total cost/kg of live bird	7.76	5.08	6.57	4.39	6.61	4.43
Total cost/kg meat	11.08	7.25	9.39	6.28	9.45	6.32
Net profit/live birds	5.95	2.27	7.65	3.36	7.57	3.31
Net profit/kg of live bird	2.74	1.05	3.93	1.73	3.89	1.70
Net profit/kg meat	3.92	1.50	5.62	2.47	5.55	2.43

Our results show that using DBP as alternative energy feed source could result in remarkable reduction of the total cost of production, thus increase net profit. Results of TB and TC did not show much variation throughout, this shows once again that the salt content had no effect on the cost of production of the two groups.

Table 4.19 shows the total production cost and net profit per live bird and per kg of live bird.

4.6.3 Total physical, average physical and marginal physical product

Total physical product (TPP), average physical product (APP) and marginal physical product (MPP) were calculated as described under **Chapter 3: Materials and Methods**, and the results are displayed in Tables 4.20 and 4.21. Input used was kg DBP and output was total live-weight in kg. It can be seen from both Tables 4.20 and 4.21 that the TPP (weight of birds) is increasing at an increasing rate, thus the marginal product of both group TB and TC remained positive throughout the production period. In other words, the addition of DBP in the diet resulted in an additional increase of weight of birds throughout the production period. The average product (APP) of TB decreased, but remained higher than the marginal product. The same was true for TC, except that MPP was higher than APP by 42 days.

Table 4.20 Level of input (DBP) and corresponding TPP, APP and MPP for group TB

DAYS	INPUTS OR FEED INTAKE (DBP)	TPP OR TOTAL WEIGHT	APP OR (Y1/X1)	DY1 OR CHANGE IN PRODUCT	DX1 OR CHANGE IN INPUT	MPP OR (DY1/DX1)
7	0.000	22.620				
14	15.850	56.891	3.59	34.271	15.850	2.16
21	52.264	105.713	2.02	48.822	36.414	1.34
28	104.054	168.991	1.62	63.278	51.790	1.22
35	167.042	256.215	1.53	87.224	62.988	1.38
42	234.128	348.221	1.49	92.006	67.086	1.37

Table 4.21: Level of input (DBP) and corresponding TPP, APP and MPP for group TC

DAYS	INPUTS OR FEED INTAKE	TPP OR TOTAL WEIGHT IN KG (Y1)	APP OR (Y1/X1)	DY1 OR CHANGE IN PRODUCT	DX1 OR CHANGE IN INPUT	MPP OR (DY1/DX1)
7	0.000	23.082				
14	14.730	55.455	3.76	32.373	14.730	2.20
21	51.989	103.088	1.98	47.633	37.259	1.28
28	112.685	168.230	1.49	65.142	60.696	1.07
35	192.002	251.035	1.31	82.805	79.317	1.04
42	247.463	348.320	1.41	97.285	55.461	1.75

In order to determine at what level a producer should operate, he must have information regarding the price of the product and the price of the input.

Tables 4.22 and 4.23 show that the total revenue of live birds (Rand), is determined by multiplying the quantity of product produced by the price of the product. Similarly, by multiplying the marginal product schedule by the price of the product, the amount by which the total revenue changes as inputs are added, can be determined (Bishop, 1958).

The amount by which the total revenue changes when an additional unit of input is added is known as the value of the marginal product (VMP). In the same manner, by multiplying the average product by the price of the product, the value of the average product (VAP) can be determined for a particular level of input (Bishop, 1958).

The value TPP, MPP and APP help to determine the most profitable level of input. If inputs are bought at a stated price (P X1), it pays to add additional units of the input until the VMP is just equal to the price of input, i.e. DBP, which had a price of zero (Bishop, 1958).

In the case of both TB and TC, the VMP remained higher than the price of the input (DBP). This shows that adding DBP during the 42 days of production period of will always pay, provided DBP remains free of charge.

Table 4.22: Total revenue, VMP and VAP in Rand for TB

DAY	CURRENT PRICES			PRICES AT TIME OF TRIAL (RAND)		
	VTP	VAP	VMP	VTP	VAP	VMP
7	339.30			197.93		
14	853.37	53.85	32.40	497.80	31.41	18.90
21	1 585.70	30.30	20.10	924.99	17.68	11.73
28	2 534.87	24.30	18.30	1 478.67	14.18	10.68
35	3 843.23	22.95	20.70	2 241.88	13.39	12.08
42	5 223.32	22.35	20.55	3 046.93	13.04	11.99

Transport costs to collect the DBP are equivalent to the transport costs of other feeds, as the bakeries and feed suppliers are both located in urban areas. Therefore, transport costs have been excluded from the calculation.

Table 4.23: Total revenue, VMP and VAP in Rand for TC

DAY	CURRENT PRICES (RAND)			PRICES AT TIME OF TRIAL (RAND)		
	VTP	VAP	VMP	VTP	VAP	VMP
7	346.23			201.97		
14	831.83	56.40	33.00	485.23	32.90	19.25
21	1 546.32	29.70	19.20	902.02	17.33	11.20
28	2 523.46	22.35	16.05	1 472.02	13.04	9.36
35	3 765.53	19.65	15.60	2 196.56	11.46	9.10
42	5 224.80	21.15	26.25	3 047.80	12.34	15.31

4.6.4 Gross margin analysis and scenario planning

Gross marginal analysis is the difference between the income of an enterprise and the direct costs associated with the enterprise. It is an economic method often used to estimate or compare the economic impact of management changes in commercial farming operations.

Gross margin analysis can also be applied in small-scale or communal farming enterprises. They should always be applied when estimating the impact of extension messages (Thrusfield, 1988; Amir & Knipscheer, 1989; Bembridge, 1991; van Schothorst, 1997).

Scenario planning, using Excel®, was done to compare the impact of the three different diets on the gross margins, using raw data. The calculations were done at the price during the trial (price then) and current price (price now). In the case of this study, certain of the production costs are the same for TA, TB and TC and have not been brought into the calculation.

Gross margin analysis should be done for farmers who contemplate entering broiler production, as well as for those who are in that business already. The start up cost of small-scale broiler production is very low, with the intention of expanding the business in future. The purchase of birds will be considered as fixed costs, the construction of the poultry house will not be considered since it is a constant for all three groups. Water supply is also a constant for all three groups and will not be costed out. Results are shown in Tables 4.24 and 4.25.

Gross margin analysis has been done using the actual prices at the time of the investigation (then) compared to the projected figures using today 's prices (now). DBP was obtained free of charge as it is a waste product (stale bread) not considered fit for human consumption.

Gross margin analysis (Table 4.25) indicated that both TB and TC gave a better gross margin than TA. This held true for both the prices at the time of the trial and projected figures at today's prices. Feed costs (Table 4.24) was almost one third less for groups TB and TC, where DBP and choice was used, than for TA, where a conventional two stage ration was used.

Table 4.24: Gross Margin Analysis (total revenue per enterprise less total variable costs) of the three groups : TA, TB and TC with two scenarios (price now and price then)

INPUT (FEED) VARIABLE COSTS	TA	TB S1	TB DBP1	TC S2	TC DBP2
1. Feed prices					
1.1 Feed prices now (R)					
Starter mash/50 kg bag	131.40	131.40		131.40	
Grower pellet/50 kg bag	127.78				
Starter mash/kg	2.63	2.63		2.63	
Grower pellet/kg	2.56				
DBP1			0.00		
DBP2					0.00
1.2 Feed prices then (R)					
Starter mash/50 kg bag	80.25	80.25		80.25	
Grower pellet/50kg bag	77.75				
Starter mash/kg	1.61	1.61		1.61	
Grower pellet/kg	1.56				
DBP1			0.00		
DBP2					0.00
2. Total intake (kg)					
Starter mash from 1 - 21 days	197.08	143.66		144.10	
Starter mash from 22 - 42 days		366.47		371.10	
Starter mash to 42 days		510.12		516.10	
Grower ration from 22 - 42 days	598.92				
DBP1 to 42 days			234.11		
DBP2 to 42 days					247.46
3. Total cost of feed intake (intake x price per kg)					
3.1 Total cost of feed now (R)					
Starter mash from 1 – 21 days	518.32	377.82		378.99	
Starter mash from 22 - 42 days		963.80		978.35	
Starter mash to 42 days		1 341.62		1 357.34	
Grower ration from 22 - 42 days	1 533.23				
DBP1 to 42 days			0.00		
DBP2 to 42 days					0.00
Subtotal (42 days)	**2 051.55**	**1 341.62**	**0.00**	**1 357.34**	**0.00**
3.2 Total cost of feed then (R)					
Starter mash from 1 – 21 days	317.30	231.29		232.01	
Starter mash from 22 - 42 days		590.01		598.92	
Starter mash to 42 days		821.30		830.93	
Grower ration from 22 - 42 days	934.31				
DBP1 to 42 days			0.00		
DBP2 to 42 days					0.00
Subtotal (42 days)	**1.251.61**	**821.30**	**0.00**	**830.93**	**0.00**

Table 4.25: Gross Margin Analysis (total revenue per enterprise less total variable costs) of the three groups: TA, TB and TC using two scenarios (price now and price then)

OUTPUT (WEIGHT OF BIRDS)	TA	TB	TC
1. Number of birds	178	179	179
2. Weight (at 42 days)			
Total live weight	386.14	348.22	348.32
Meat yield in %	70	70	70
Total slaughter weight	270.21	243.75	243.82
3. Sale of birds in (R)			
Sale of birds/kg now	15.00	15.00	15.00
Sale of birds/kg then	8.75	8.75	8.75
4. Total Revenue (R)			
Total revenue now	4 054.49	3 656.31	3 657.36
Total revenue then	2 365.12	2 132.85	2 133.46
5. Total variable cost (R)			
Total variable cost now	2 051.55	1 341.62	1 357.34
Total variable cost then	1 251.61	821.29	830.92
6. Gross margin on total liveweight (R)			
Gross margin now	2 002.93	2 314.70	2 300.02
Gross margin then	1 113.51	1 311.55	1 302.53
7. Total variable cost/bird in(R)			
Total cost per bird now	11.46	7.54	7.63
Total cost per bird then	6.70	4.62	4.70
8. Gross margin per bird (R)			
Gross margin now	11.26	12.93	12.85
Gross margin then	6.26	7.33	7.28

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This study confirms the central hypothesis that the use of DBP with starter ration, as part of a choice feeding system has a financial advantage over a two-stage (starter plus grower ration) feeding system for small-scale broiler enterprises.

5.1 Conclusions

The use of DBP in groups TB and TC resulted in a reduction of the feed costs by nearly a third and consequently had a positive impact on the total cost of production, net profit and gross margin analysis per live bird and per kg of live birds in contrast to the control group (TA). This held true both for feed costs and income at the time of the trial and for a projected cost-benefit scenario using current prices.

This study has also confirmed that chickens are able to self-select their diets when raised under choice situations. This is shown by the performance of birds in terms of body weight, feed intake , feed conversion, mortality and necropsy results. Groups TB and TC had similar body weights, feed intake, mortality % and feed conversion. The feed conversion was slightly better for groups TB and TC than for TA, although the difference was not statistically significant. This suggests that the conversion of DBP into kg liveweight of chickens in groups TB and TC, was at least as efficient as the control diet (TA).

The higher feed intake and body weight in TA was possibly partly due to the physical form of the feed (pelleted feed which is normally given to broilers from 3 weeks of age), and suggests that the physical form of feed may be of importance and should be considered in the future. On the other hand, the salt content did not affect the choice of feed by groups TB and TC. DBP contained a higher salt percentage than the commercial starter (S1) ration. However, no significant difference was found between the intake of the normal (S1) and low salt (S2) starter rations used respectively in groups TB and TC. In other words, salt content did not influence the choice of the birds.

It is probable that the choice of DBP or starter in groups TB and TC was a result of energy and mainly protein requirements. Requirements for protein are higher in the beginning and decrease with age of the birds: 22% (1 – 21 days) and 20% (22 – 35 days) and lower at the last stage 18% (36 – 42 days). Requirements for energy are lower at the early stage of the production cycle and higher at the end: 12.94 ME MJ/kg (1 - 21 days), 13.35 ME MJ/kg (22 - 35 days) and 13.81 ME MJ/kg (36 - 42 days).

Initially, the proportion of DBP was low, then increased rapidly and levelled out after 4 weeks (28 - 35 days), even decreasing slightly in the last week of the experiment. The intake of starter rations remained higher than that of DBP throughout the experiment, probably because the starter ration was closer to optimum.

In other words, the birds used free choice to provide themselves with a "grower" and "finisher" ration using the DBP and starter ration as ingredients. This is the type of choice or selection that wild animals and birds use to balance their diets and is a natural mechanism. It is used in the context of this study to save the small-scale resource-limited poultry producer the expense of balancing rations using mathematics or computer programmes. In small-scale systems (500 – 2 000 birds) it is not economical to use pre-mixed rations in three stages as the broiler producer invariably lands up with partly used bags of feed. Therefore, in practice, most use a two-stage system. The inclusion of DBP means that only one type of feed is purchased and this is supplemented by an affordable and available source of energy, i.e. DBP. Currently, bakeries do not charge for DBP and Boerstra Bakery, the main supplier of bread, operates in all urban areas, so it is as available as are Feed Merchants in such areas.

A poultry producer, who has to organise transport for his poultry feed, can simultaneously arrange for collection of stale bread. Drying and pulverising of stale bread to produce DBP may be relatively labour intensive, however this is not much of a problem for the small-scale producer who has more access to labour (his own and his family's) than to capital.

DBP tested negative for aflatoxins, that shows that DBP could be safely used in small-scale broiler production, provided that producers use care in discarding bread that is visibly mouldy. In practice it was seen that this is a very small proportion of the bread.

5.2. Recommendations

The following extension messages could be used by veterinarians, animal health technicians and extension officers advising small-scale poultry producers:

- DBP can be used on a free choice basis in small-scale broiler systems (500 - 2 000 birds) to reduce feed costs.
- Although specimens tested during this study were negative, aflatoxin may be a problem if the bread is incorrectly handled and small-scale producers should be warned not to use mouldy bread
- DBP free choice may be a problem for large-scale broiler producers as sufficient DBP may not be locally available to meet their needs.

REFERENCES

1. Acar, N., Moran, E.T & Bilgili, S.F. 1991 Live performance and carcass yield of male broilers from two commercial strain crosses receiving rations containing lysine below and above the established requirement between six and eight weeks of age. *Poultry Science*, 70: 2315-2321

2. Agwanobi, L.N. 1993 Sweet potato [*Ipomea batatas (L.) Lam.*] meal as a partial substitute for maize in layer's rations. *Tropical Agriculture* (Trinidad), 70 (3): 291-293

3. Agwanobi, L. N. 1995 The effects of sweet potato [*Ipomea batatas (L) Lam*.] peel as a maize replacement on layer performance in chickens. *Tropical Agriculture (Trinidad)*, 72: 330-332

4. Amir, P. & Knipscheer, H.C. 1989 *Conducting on farm animal research*: *procedures and economic analysis*. Winrock International Institute for Agricultural Development and International Development Research Centre. Waginingen, The Netherlands: 1–10

5. Anandajayasekeram, P., Martella, D.R. & Rukuni, M. 1986 *A training manual for biological scientists on impact assessment of investments in agricultural and natural resources research*. Regional Agricultural Advisor, University of Zimbabwe: 95-98

6. Appleby, M.C. 1992 Behaviour, management and welfare. *In*: Appleby, M.C., Hughes, B.O. & Elson, H. A. (Eds), *Poultry production systems, Behaviour, Management and Welfare*. CAB international. Redwoob Press LTD, Melksham. Great Britain: 105-205

7. Austic, R.E. & Scott, M.L. 1997 Nutritional diseases. *In*: Calnek, B.W., Barnes, H.F., Beard, C.W., McDougald, L.R & Saif, Y.M. (Eds), *Diseases of Poultry.* 10th ed. Iowa State University. Ames, Iowa, U.S.A: 47-48

8. Austic, R.E. 1990 Houses and equipment. *In*: Austic, R.E & Nesheim, M.C. (Eds), *Poultry Production*. 16th ed. Lee and Feibiger. Philadelphia, London: 139-170

9. Baker, D.H. & Han, Y. 1994 Ideal amino acid profile during the first three weeks post hatching. *Poultry Science*, 73: 1441-1447

10. Balog, J.M & Millar, R.J. 1989 Influence of the sense of taste on broiler chick feed consumption. *Poultry Science,* 68: 1519-1526

11. Ban, A.W. Van Den. 1988 Extension and extension education. *In*: Ban, A.W. Van Den & Hawkins, H.S. (Eds), *Agricultural Extension.* Longman Scientific & Technical. U.S.A. New York: 7–35

12. Ban, A.W. Van Den. 1996 Extension and extension education. *In*: Ban, A.W. Van Den & Hawkins, H.S. (Eds), *Agricultural Extension. 2nd Ed.* Oxford: Blackwell Science: 7–18

13. Barley, H.S., Slinger, S.J., Aitken, J.R., Biely, J., Clandinin., D.R., O'Neil, J.B, Robblee, A.R. & Sell., J.L. 1968a The influence of method of crumbling diets containing different levels of protein and lysine on chick performance. *Poultry Science,* 47: 677-687

14. Barley, H.S., Summers J.D. & Slinger S.J. 1968b The influence of steam pelleting conditions on the nutritional value of chick diets. *Poultry Science,* 47: 931-939

15. Barnes, H.J. & Gross, W.B. 1997 Colibacillosis. *In*: Calnek, B.W., Barnes, H.F., Beard, C.W., McDougald, L.R & Saif, Y.M. (Eds), *Diseases of Poultry.* 10th ed. Iowa State University. Ames, Iowa, U.S.A: 131-159

16. Bembridge, T.J. 1991 *Communication in agricultural extension: Practical Guidelines for Agricultural Extension Workers, a Field Manual*. Development Bank of Southern Africa: 13–15

17. Bishop,C.E. 1958 Production function. In: . Bishop, C.E & Toussaint, W.D (Eds), *Introduction to Agricultural Economic Analysis.* New York: Wiley and company: 28–67

18. Blake, A.G., Mather, F.B. & Cleaves, E.W. 1984 Dietary-self selection of laying hens inadequate to overcome the effects of high environmental temperatures. *Poultry Science*, 63: 1346-1349

19. Boling, S.D., Douglas, M.W., Johnson, M.L., Wang, X., Parsons, C.M., Koelkebeck, K.W. & Zimmerman, R.A. 2000a The effects of dietary available phosphorus levels and phytase on performance of young and older laying hen. *Poultry Science,* 79: 224-230

20. Boling, S.D., Douglas, M.W., Shirley, R.B., Parsons, C.M. & Koelkebeck, K.W. 2000b The effects of various dietary levels of phytase and available phosphorus on performance of laying hens. *Poultry Science,* 79: 535-538

21. Buckett, M. 1988 Basic economic principles of production*: In:* Buckett, M. (Ed), *An Introduction to Farm Organisation and Management*. 2nd ed. Pergamon Press: Oxford. New York, Beijing, Frankfurt, Sao Paulo, Sydney, Tokyo, Toronto: 32–33

22. Bradford, M.M.V. & Gous, R.M. 1991a The response of growing pigs to a choice of diets differing in protein content. *Animal Production,* 52: 185-192

23. Bradford, M.M.V. & Gous, R.M. 1991b A comparison of phase feeding and choice feeding as methods of meeting the amino acid requirements of growing pigs. *Animal Production*, 52: 323-330

24. Brody, T.B., Cherry, J.A. & Siegel, P.B. 1984 Responses to dietary self-selection and calories in liquid form by weight selected lines of chickens. *Poultry Science*, 63: 1626-1633

25. Brown, H.B. & McCartney, M.G. 1982 Effects of dietary energy and protein and feeding time on broiler performance. *Poultry Science,* 61: 301-310

26. Brown, T. & Jordan, F.T.W. 1999 Other diseases, poisons & toxins. *In:* Jordan, F.T.W., Pattison, M., Alexander, D. & Faragher, T. (Eds), *Poultry diseases* 5th ed. Bailliere Tindall, Churchill Livingstone, Mosby, W.B. Saunders London, Edinburg, New York, Philadelphia, St Louis, Sydney, Toronto: 457-483

27. Calet, C. 1965 The relative value of pellets versus mash and grain in poultry nutrition. *World's Poultry Science Journal* , 21: 23–52

28. Carre, B., Escartin, R., Melcion, J.P., Champ, M., Roux, G. & Leclercq, B. 1987 Effect of pelleting and association with maize or wheat on the nutritive value of smooth peas (*Pisum sativum*) seeds in adults cockerels. *British Poultry Science,* 28: 219-229

29. Casavant, K.L. 1999 Physical production relationships. *In*: Casacant, K.L., Infanger, C.L. & Bridges, D.E (Eds), *Agricultural Economics and Management*. Prentice Hall. Upper Saddle River, New Jersey: 26–51

30. Cave, N.A & Burrow, V.D. 1993 Evaluation of naked oat (*Avena nuda*) in the broiler chicken diet. *Canadian Journal of Animal Sciences,* 73: 393-399

31. Council for scientific and industrial research (CSIR) 1997 Food science and technology. Mycotoxins in poultry feed in South Africa. *Poultry Bulletin* , August: 376-378

32. Cowan, P.J. & Michie, W. 1978 Choice feeding of the male and female broiler. *British Poultry Science*, 19: 149-152

33. Cowan, P.J. & Michie, W. 1978b Environmental temperature and broiler performance: the use of diets containing increasing amount of protein. *British Poultry Science,* 19: 601-605

34. Daguro, A. E. & Rivas, E.T. 1987 Cassava as a source of energy for broiler production. *CMU Journal of Agriculture, Food and Nutrition*, 9: 49-59

35. Dale, M.N., Pesti, G.M. & Rogers, S.R. 1990 True metabolizable energy of dried bakery product. *Poultry Science,* 69: 72-75

36. Damron, B.L., Waldroup P.W. & Harms R.H. 1965. Evaluation of dried bakery products used in broiler diets. *Poultry Science*, 44: 1122-1126

37. Day, E.J. & Dilworth, B.C. 1968 *Dried bakery products in broiler diets.* Mississippi State University Experimental Station Bulletin. *763*. Mississipi State University, Mississipi, USA

38. Devendra, C. 1993 The small farm scenario. In: FAO of the United Nations, Rome. *Sustainable animal production from small farm systems in Southeast Asia.* FAO animal production and health paper 106. Internet. Chapter 2. http://www.fao.org/docrep/003/to757e/T0757E00.htm. Access:27/06/02, 15: 20

39. Dominiguez, P.L. 1992 Feeding of sweet potato to monogastrics. *FAO Animal Production and Health Paper*, 95: 217-233

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

41. Du Toit, D. 2001 The department of agriculture's perspective on the poultry industry. *Poultry Bulletin,* June: 247-262

42. El Boushy A.R.Y. 2000a The benefit of feed from waste. *In*: El Boushy A.R. Y & Van deer Pole, A.F.B. (Eds), *Formulating Feed From Waste and by-products.* 2nd Ed. Kluwer Academic Publishers: 1-28

43. El Boushy A.R.Y. 2000b Fruit, vegetable and brewers' Waste. *In* : El Boushy A.R.Y. & Van der Poel, A.F.B. (Eds), *Formulating feed from waste and by-Products*. 2nd ed. Kluwer Academic Publishers: 173-301

44. Edwards, H.M., & Veltmann,Jr., J.R. 1983 The role of calcium and phosphorus in the aetiology of tibial dyschondroplasia in young chicks. *Journal of Nutrition* , 113: 1568-1575

45. Edwards, H.M., Fernandez, III, S.R. & Baker, D.H. 1999 Maintenance lysine requirement and efficiency of using lysine for accretion of whole-body lysine and protein in young chicks. *Poultry Science,* 78: 1412-1417

46. Emmans, G.C. 1975 Problems in feeding laying: can a feeding system based on choice solve them? *World's Poultry Science Journal*, 31: 31

47. Emmans, G.C. 1977 The nutrient intake of laying hens given a choice of diets, in relation to their production requirements. *British Poultry Science,* 18: 227-236

48. Emmans, G.C. 1978 Free-choice feeding of laying poultry. Recent Advances. *In*: Haresign, W. & Lewis, D. (Eds), *Animal Nutrition*. Butterworths. London, UK: 31-39

49. Emmerson, D.E., Denbow, D.M. & Hulet, R.M. 1990 Protein and energy self-selection of turkey breeder hens: reproductive performance. *British Poultry Science,* 32: 555-564

50. Emmerson, D.E., Denbow, D.M., Hulet, R.M , Potter, L.M. & Van krey, P. 1991 Self-selection by dietary protein and energy by turkey breeder hens. *British Poultry Science,* 31: 283-292

51. Eruvbetine, D. & Afolami, C. A. 1996 Economic evaluation of cassava (*Manihot esculenta*) as an ingredient for broilers. *Proceedings of the XIX world poultry congress Amsterdam*. 20 - 24 September, 3**:** 532-535

52. Ewing, W.R. 1951 Minerals in poultry ration. *In*: Ewing, W.R (Ed), *Poultry Nutrition.* 4th ed. South Pasadena, California: 484-508

53. Fetuga, B.L. & Oluyemi, J.A 1976 The metabolisable energy of some tropical tuber meals for chicks. *Poultry Science,* 55: 868-873

54. Fisher, C. 1986. Major minerals in the nutrition of poultry. *In:* Fisher, C & Boorman, K.N. (Eds), *Nutrient Requirements of Poultry and Nutritional Research*. Butterworth & Co: 141-154

55. Forbes, J.M. & Shariatmadari, F. 1994. Diet selection for protein by poultry. *World's Poultry Science Journal*, 50: 7-24

56. Fowler, N.G. 1996. Nutritional disorders. *In*: Jordan, F.T.W & Pattison, M (Eds), *Poultry Diseases*. 4th ed. W.B. Saunders Company Ltd., London, Philadelphia, Toronto, Sydney, Tokyo: 306-332

57. Funk,E.M. 1932. Can the chick balance its ration? *Poultry Science,* 11: 94–97

58. Gerpatio, A.L., Pascal, F.S., Querubi, L.J., Vergel de Dios, A.F. & Mercado, C.L. 1978. Evaluation of tuber meals as energy sources. 1. Sweet potato and cassava based rations for broilers. *Philippine Agriculturist*, 61: 395–410

59. Glasser, A.A. 1997 Economics of broiler production. *Poultry Bulletin,* May: 178–183

60. Graham, W.R. 1932. Can we learn anything from a free choice of feeds as expressed by chicks? *Poultry Science,* 11: 365-366

61. Guèye, E.F. 2000 Uncertain future for Africa's commercial poultry industry. *World Poultry,* 16 (5): 12-16

62. Guèye, E.F. 2001 Marketing of family poultry products in Africa to be improved. *World Poultry,* 17 (5): 12-14

63. Halvorson, D.B. & Jacobsen, M. 1970. Variations in the development of muscles in chickens. *Poultry Science,* 49: 132-136

64. Harms, R.H., Damron, B.L. & Waldroup, P.W. 1966. Dried bakery product as an ingredient for poultry feeds. *Feedstuffs,* 38: 42-43

65. Heady, E.O. 1965. Basic principles in farm management. *In*: Heady, E.O. & Jensen, H.R. *Farm management economics*. 8th ed. Prentice-Hall, Inc: 54–90

66. Henry, M.H & Wyatt, R.D. 2001. The toxicity of fumonisin B1, B2 and B3, individually and in combination, in chicken embryos. *Poultry Science*, 80: 401-407

67. Hill, F.W., Anderson, D.L., Renner, R. & Carew, L.B. 1960. Studies of the metabolizable energy of grain products for chickens. *Poultry Science,* 39: 573-579

68. Hoerr, F.J. 1997. Poisons and Toxins. *In:* Calnek, H.J., Barnes, C.W., Beard, L.R. McDougald & Y.M. Saif, (Eds). *Diseases of Poultry*, 10th ed. Iowa State University Press Ames, Iowa, USA: 951-979

69. Hollinger, K. & Ekperigin, H.E. 1999 Mycotoxicoses in food producing animals. V*eterinary Clinics of North America-Food Animal Practice,* 15: 133-163

70. Holocombe, D., Roland, D.A. & Harms, R.H. 1975. The ability of hens to adjust calcium intake when given a choice of diets containing two levels of calcium. *Poultry Science*, 54: 552-561

71. Holocombe, D., Roland, D.A. & Harms, R.H. 1976a The ability of hens to regulate protein intake when offered a choice of diets containing different levels of protein. *Poultry Science*, 55: 1731-1737

72. Holocombe, D., Roland, D.A. & Harms, R.H. 1976b The ability of hens to regulate phosphorus intake when offered a choice of diets containing different levels of phosphorus. *Poultry Science*, 55: 1731-1737

73. Horwitz, W. 2000 . *In*: Horwitz, W. (Ed), *Officials methods of analysis of AOAC international: Agricultural chemicals; contaminants*; *Drugs,* 17th ed. Volume 2, Bread. AOAC International. Gaithersburg, Maryland 20877-2417 USA. 46-50

74. Huff, W.E. & Doerr, J..A. 1981 Synergism between aflatoxin and ochratoxin in broiler chickens. *Poultry Science,* 60: 550-555

75. Hughes, B.O. 1984 The principles underlying choice feeding behaviour in fowls with special reference to production experiments. *World's Poultry Science Journal*, 40: 141-150.

76. ILCA (International Livestock Center for Africa) 1990 *Livestock systems research manual*. Working Paper 1, Vol.1. ILCA, Addis Ababa, Ethiopia: 5–7

77. Job, T.A., Oluyemi, J.A., & Entonu, S. 1979 Replacing maize with sweet potato in diets of chicks. *British Poultry Sciences,* 20: 515-519

78. Jordan, F.T.W. 1996 Some Poisons and Toxins. *In*: Jordan, F.T.W & Pattison, M (Eds), *Poultry Diseases*. 4th ed. W.B. Saunders Company Ltd., London, Philadelphia, Toronto, Sydney, Tokyo: 333-342

79. Kautz, W.P. 1998 Toxicology and quality evaluation of foraged and silages. *In:* Howard J.L., Smith R.A. (Eds): *Current Veterinary Practice*, 4: *Food Animal Practice*. Philadelphia, W.E. Saunders: 239-242

80. Kempster, H.L. 1916 Food selection by laying hens. *Journal of the American Association of Institutions and Investigators in Poultry Husbandry*, 3: 26-28

81. Khajajern, S & Khajajern, M. 1985 Roots and Tubers as cereal substitutes. *FAO animal production and health paper*, 63: 79–90

82. kleyn, R. 1992 Broiler feeding for better returns. *Poultry Bulletin,* July: 283-286

83. Koster, E. & Coetzee, C. 1996 Poultry farming systems for small commercial farmers. *Poultry Bulletin,* September: 428-429

84. Kubena,L.F., Huff, W.E., Deaton, J.W., Reece, F.N., May, J.D. & Vardaman, T.H. 1972 The influence of temperature and sex on the amino acid requirements of the broiler. *Poultry Science*, 51: 1391-1396

85. Kubena, L.F., Harvey, R.B., Huff, W.E., Corrier,D.E., Phillips, T.D. & Rottinghaus, G.E. 1990 Efficacy of hydrated sodium calcium alumuminosilicate to reduce the toxicity of aflatoxin and T-2 toxin. *Poultry Science*, 69: 1239–1247

86. Kubena, L.F., Harvey, R.B., Phillips, T.D, Corrier, D.E. & Huff, W. 1990 Diminution of aflatoxicosis in growing chickens by dietary addition of a hydrated, sodium calcium aluminosilicate. *Poultry Science,* 69: 727–735

87. Kyriazakis, I. 1995 Choice feeding of farm animals: attractions and limitations. *Feed Mix*, 3 (2): 24

88. Leeson, S. & Summer, J.D. 1978 Dietary self-selection for energy and protein by pullets and broilers. *British Poultry Science,* 19: 425-430

89. Leeson, S. & Summer, J.D. 1991 Minerals. In: Leeson, S. & Summer, J.D. (Eds),*Commercial Poultry Nutrition.* 2nd ed. University Books Guelph, Ontario, Canada: 15-36

90. Leeson, S., Caston, L. & Simmers, J.D. 1996 Broiler response to energy diets. *Poultry Science*, 75: 529–535

91. Leeson, S. 1997 Minerals. *In:* Leeson, S. & Summer, J.D. (Eds), 1997 *Commercial Poultry Nutrition.* 2nd ed. University Books Guelph, Ontario, Canada: 55

92. Le Roux, C.D. 2000 Personal communication. Lecture. Department of Production Animal Studies, Faculty of Veterinary Science, University of Pretoria

93. Marasas, W.F.O., Jeskiewicz, K., Venter, F.S. & Van Schalkwyk. 1981 *Fusarium moniliforme* contamination of maize in oesophageal cancer areas in Transkei. *South African Medical Journal,* 74: 110-114

94. Marijanovic, D.R., Holt, P., Norred, W.P., Bacon, C.W., Voss, K.A. & Stancel, P.C. 1991 Immunosuppressive effects of *Fusarium moniliform* corn cultures in chickens. *Poultry Science,* 70: 1895-1901

95. McCrindle, C.M.E. 1998 Poultry: actual needs seen during field investigations. *Veterinary Needs Appraisal*: *Zuurbekom area, Gauteng*. January, 24: 14

96. McCrindle, C.M.E. 1998 The community development approach to animal welfare: an African perspective. *Applied Animal Behaviour Science*, 59: 227–233

97. Miazzo, R., Rosa, C.A.R., De Queiroz Carvalho, E.C., Magnoli, C., Chiacchiera, S.M., Palacio, G., Saenz, M., Kikot, A., Basaldela, E. & Dalcero, A. 2000 Efficacy of synthetic zeolite to reduce the toxicity of Aflatoxin in broiler chicks. *Poultry Science*, 79: 1-6

98. Monnikhof, M.O. 1997 The poultry industry, world wide. *Poultry Bulletin, M*ay: 189-200

99. Mongin, P & Sauveur, B. 1974 Voluntary food and calcium intake by the laying hen. *British Poultry Science,* 15: 349-359

100. Moran, E.T. 1980 Impact of reducing finishing feed energy - protein level on performance, carcass yield, and grade of broiler chickens. *Poultry Science,* 59: 1304-1310

101. Moran, E.T., Summers, J.D & Pepper, W.F. 1970. Nutritional evaluation of selected milling fractions from wheats of different type and geographical area of production: First three limiting essential amino acids for the chick and performance under dietary conditions calculated adequate. *Poultry Science,* 49: 371-387

102. Moran, E.T., Jr. & Bilgili, S.F. 1990 Processing losses, carcass quality and meat yields of broiler chickens receiving diets marginally deficient or adequate in lysine prior to marketing. *Poultry Science,* 69: 702-710

103. Morrison, F.B., 1959 *Feeds and Feeding*. The Morrisson Publishing Company, Clinton, Iowa

104. Munt, R.H.C., Dingle, J.G. & Sumpa, M.G. 1995 Growth, carcass composition and profitability of meat chickens given pellets, mash or free-choice diet. *British Poultry Science,* 36: 277-284

105. National Research Council 1994 *Nutrient requirements of poultry*. 9th Revised edition, National Academy Press, Washington, DC

106. Naude, R.T. 1992 Poultry industry's input costs must not increase dramatically and efficiency must progress. *Poultry Bulletin*, January: 14–18

107. Nir, I., Melcoin, J.P. & Piccard, M. 1990a. Effect of particle size of sorghum on feed intake and performance, gastrointestinal tract and behaviour of meat type chickens. *British Poultry Science,* 69: 2177–2184

108. Nir, I.,Melcton, J.P & Picard, M. 1990b Effect of particle size of sorghum grains on feed intake and performance of young broilers. *Poultry Science,* 69: 2177-2184

109. Nir, I., Twina, Y., Grossman, E. & Nitsan, Z. 1994 Quantitative effects of pelleting on performance, gastrointestinal tract and behavior of meat type chickens. *British Poultry Science,* 35: 589-602

110. Noktula, N. 2000 Personal communication from Regional Veterinarian at Rainbow Farms, Hammarsdale. Kwazulu Natal, S.Africa

111. North, M.O. 1990a Broiler, Roaster and Capon Management. *In*: North, M.O. & Bell. D.D. (Eds), *Commercial Chicken Production Manual*. 4th ed. New York: Chapman & Hall San Diego, California: 453-546

112. North, M.O. 1990b Feeding Broiler, Roaster and Capon. *In*: North, M.O. & Bell. D.D. (Eds),*Commercial Chicken Production Manual*. 4th ed. New York: Chapman & Hall San Diego, California : 721-740

113. North, M.O 1990c Vitamins, minerals and trace ingredients. *In*: North, M.O. & Bell. D.D. (Eds), *Commercial Chicken Production Manual*. 4th ed. New York: Chapman & Hall San Diego, California : 587-613

114. Okumura. J. & Mori, S. 1979 Effects deficiencies of single essential amino acids on nitrogen and energy utilisation in chicks. *British Poultry Science,* 20: 421-429

115. Olver, M.D & Jonker, A. 1997 Effects of choice feeding on the performance of broilers. *British Poultry Science*, 38: 571-576

116. Osborne, D.J., Huff, W.E, Hamilton, P.B. & Burmeister, H.R. 1982 Comparison of Ochratoxin, Aflatoxin, and T-2 toxin for their effect on selected parameters related to digestion and evidence for specific metabolism of carotenoids in chickens. *Poultry Science*, 61: 2247–2254

117. Paster, N. & Lister, N. 1982 The nutritional value of moldy grains for broiler chicks. *Poultry Science,* 61: 2247-2254

118. Patrick, H. 1980 Nutrition of minerals. *In:* Patrick, H. & Schaible, P.J. (Eds) *Poultry: Feeds & Nutrition*. 2nd ed. The Avi Publishing Company. Inc. Westport, Connecticut: 157-185

119. Patterson, P.H., Sunde, E.L, Schieber, E.M & White, W.B. 1988 Wheat middlings as an alternative feedstuffs for laying Hens. *Poultry Science,* 67: 1329-1337

120. Penson, Jr. J.B. 2002 Introduction to production and resource use. *In*: Penson, Jr. J.B., Capps,Jr. O. & Rosson III, C.P. (Eds), *Introduction to Agricultural Economics*. 3rd ed. Prentice Hall. Upper Saddle River, New Jersey: 141-167

121. Phillips, T.D., Abo-Norag, M., Edrington, T.S., Kubena, L.F., Harvey,R.B. 1995 Influence of a hydrated sodium calcium aluminosate and virginiamycin on aflatoxicosis in broiler chicks. *Poultry Science*, 74: 626-632

122. Pitt, J.I. & Udagawa, S. 1980 Taxonomy of mycotoxin producing fungi. In Kurata H, Ueno Y (Eds): *Toxigenic Fungi-Their Toxins and Health Hazard. Proceedings of the Mycotoxin Symposium Held During the 3rd International Mycological Congress in Tokyo*, Elsevier, NewYork: 75-77

123. Planvnik, I., Wax., E., Sklan, D., & Hurwitz., S. 1997 The response of broiler chickens and turkeys poults to steam-pelleted diets supplemented with fat or carbohydrates. *Poultry Science*, 76: 1000-1006

124. Plumstead, P. 1997 Practical aspects to consider in broiler nutrition. *Poultry Bulletin (ISBN-0257-201X)*, March: 109-114

125. Proudfoot, F.G., & Hulan, H.W. 1982a Feed texture effects on the performance of turkey and broiler. *Poultry Science,* 61: 327–330

126. Proudfoot, F.G. & Hulan, H.W. 1982b Effects of reduced feeding time using all mash or crumble pellet dietary regimens on chicken broiler performance, including the incidence of acute death syndrome. *Poultry Science,* 61: 750-754

127. Raju, M.V.L.N. & Devegowda, G. 2000 Influence of esterified-glucomannan on performance and organ morphology, serum biochemistry and haematology in broilers exposed to individual and combined mycotoxicosis (aflatoxin, ochratoxin and T-2 toxin). *British Poultry Science,* 41: 640-650

128. Ravindran, V. & Rajaguru, A.S.B. 1985 Nutrient contents of some unconventional poultry feed. *Indian Journal of Animal Science*, 55: 58-61

129. Reece, F.N., Lott, B.D. & Deaton, J.W. 1986 The effects of hammer mill screen size on ground corn particle size, pellet durability, and broiler performance. *Poultry Science,* 65: 1257-1261

130. Reece, F.N., Lott, B.D. & Deaton, J.W. 1985 The effect of food form, grinding method, energy level and gender on broiler performance in a moderate (21^{o}C) environment. *Poultry Science,* 64: 1834-1839

131. Reddy, C. V. & Quadratullah, S. 1996 Strategic feeding supplementation through locally available resources. *Proceedings XX World's poultry congress*, 1: 3-15

132. Riddel, C. 1997 Developmental, metabolic, and other noninfectious disorders. *In:* Calnek, H.J., Barnes, C.W., Beard, L.R., McDougald & Y.M. Saif, (Eds). *Diseases of Poultry*, 10th ed. Iowa State University Press Ames, Iowa, USA: 913-951

133. Roenigk, P.W. 1999 Symposium: muscle and development. World Poultry consumption. *Poultry Science*, 78: 72 -728

134. Rose, S.P., Burnett, A. & Elmajeed, R.A. 1986 Factors affecting the diet selection of choice fed broilers. *British Poultry Science*., 27: 251–224

135. Rugg, W.C. 1925 Feeding experiments, free choice of feeds. *Victoria, Australia*, *Department of Agricultural Bulletin*, 54: 36-56

136. Sainsbury, D. 2000 Poultry Nutrition. In: Sainsbury, D. (Ed), *Poultry health and management, chickens, Ducks, Turkeys, Geese, Quail*. 4th ed. Blackwell Science. Cambridge University: 22–30

137. Saleh, E. A., Watkins, S.E. & Waldroup, P. W. 1996 High-level usage of dried bakery product in broiler diets. *Journal of Applied Poultry Research*, 5**:** 33-38

138. Saunders, R.M., Walker, Jr.,H.G. & Kolher, G.O. 1969 Aleurone cells and digestibility of wheat mill feeds. *Poultry Science,* 48: 1497-1503

139. Scott, M.L., Nesheim, M.C & Young, R.J. 1976. Essential inorganic elements. *In*: Scott M.I. and Associates (Eds). *Nutrition of the Chicken*. 2nd ed. Ithaca, New York: 274 - 379.

140. Schaible, P.J. 1976 Feed manufacturing. *In:* Schaible, P.J. (Ed), *Poultry*: *Feeds & Nutrition.* 2nd ed. The Avi Publishing Company. Inc. Westport, Connecticut: 487-517

141. Schutte, J.B & Pack, M. 1995 Sulphur amino acid requirement of broiler chicks from fourteen to thirty-eight days of age, 1. Performance and carcass yield. *Poultry Science,* 74: 480-487

142. Sharma, R.P. & D.K.,Salunkhe 1991 Introduction to Mycotoxins. *In Sharma RP, Salunkhe, D.K. (Eds.), Mycotoxins and Phytoalexins*. Boca Raton, CRC Press: 1-12

143. Shariatmadari, F. & Forbes, J.M. 1993 Growth and food intake responses to diets with different protein contents and a choice between diets containing two concentrations of protein in broiler and layer strains of chicken. *British Poultry Science,* 34: 959-970

144. Si, J., Fritts, C.A., Burnham, D.J. & Waldroup, P.W. 2001 Relationship of dietary lysine level to the concentration of all essential amino acids in broiler diets. *Poultry Science,* 80: 1472-1479

145. Sibbald, I.R & Wolynetz, M.S. 1986 Effects of dietary lysine and feed intake on energy utilisation and tissue synthesis by broiler chicks. *Poultry Science*, 65: 98-105

146. Siegel, P.B., Picard, M., NIR, I., Dunnington, E.A., Willemsen, M.H.A. & Williams, P.E.V. 1997 Responses of meat-type chickens to choice feeding of diets differing in protein and energy, from hatch to market weight. *Poultry Science*, 76: 1183-1192

147. Sinurat, A.P & Balnave, D. 1986 Free-choice feeding of broilers at high temperatures. *British Poultry Science,* 27: 577-584

148. Sinyangwe, P.G. 1999 Poultry farming in Africa. *Poultry Bulletin* (ISBN-0257-201X) June: 382

149. Smith, J.W & Hamilton, P.B. 1970 Aflatoxicosis in the broiler chicken. *Poultry Science,* 44: 207-215

150. Summers,J.D., Slinger, S.J., Pepper, W.F., Moran, E.T. 1968 Biological evaluation of selected wheat fractions from nine different wheat samples for energy and protein quality*. Poultry Science,* 57: 1753-1760

151. Swanson, B.E. & Claar, J.B. 1984 History and development of agricultural extension. In: Swansso, B.E (Ed). *Agricultural Extension a Reference Manual*. 2nd ed. Food & Agricultural Organization of the United Nations, Rome: 1-3

152. Thrusfield, M.V. 1988 *Veterinary Epidemiology.* Butterworths, London

153. Tung., H.T. & Hamilton P.B., 1973: Decreased serum carotenoids during aflatoxicosis. *Poultry Science,* 52: 80-83

154. Van Schothorst, M. 1997. Practical approaches to risk assessment. *Journal of Food Protection*, 60 (11): 1439–1443

155. Vohra, P, Bersh, S., Qualset, C.O., Becker, R. 1991. Tritical: an alternative cereal grain in broiler starter diets. *California Agriculture*, 45 (5): 34-37

156. Waldroup, P.W., Whelchel, D.L. & Jhonson, Z.B. 1982. Variation in nutrient content of samples of dried bakery product. *Animal Feed Science and Technology*, 7: 419-421

157. Wilson, H.R & Nesbeth, W.G. 1980. Pellet *versus* mash for starting bobwhite quail. *Poultry Science,* 59: 932-934

158. Yan, F., Kersey, J.K. & Waldroup, P.W. 2001. Phosphorus requirements of broiler chicks three to six weeks of age as influenced by phytase supplementation. *Poultry Science,* 80: 455-459

159. Yo, T., Siegel, P.B., Faure, J.M. & Picards, M. 1998 Self-selection of dietary protein and energy by broilers grown under a tropical climate; adaptation when exposed to choice feeding at different ages. *Poultry Science*, 77: 502-508

160. Yo, T., Siegel, P.B., Guerin, H. & Picards, M. 1997 Self-selection of dietary protein and energy by broilers grown under a tropical climate; effect of feed particle size on the feed choice. *Poultry Science*, 76: 1467-1473

161. Yoshida, M. & Morimoto, H. 1958 The nutritive value of sweet potato as a carbohydrate source in poultry feeds. *World's Poultry Science Journal*, 14: 246.