GROWTH, CARCASS COMPOSITION AND PROFITABILITY OF BROILERS GIVEN POST-FINISHER OR FREE-CHOICE GRAIN CEREAL

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this Assignment is my own work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: Date:

ABSTRACT

Broilers of a mixed sex aged 4 weeks were used to determine whether feeding program affected the performance and profitability of birds. The performance of the birds was measured in terms of feed intake, live weight gain and carcass composition. Financial analyses were carried out to determine which of the feeding programs would be economically efficient in terms of feed cost per live weight gain.

The feeding programs followed were (i) a complete diet, (ii) free choice feeding of a complete diet with cereal grains, and (iii) cereal grain fed solely. The treatments used were:

1) Post-finisher diet as a control,
2) Post-finisher plus cracked yellow maize,
3) Post-finisher plus whole wheat,
4) Post-finisher plus whole sorghum,
5) Cracked yellow maize,
6) Whole wheat and
7) Whole sorghum

The experiment was conducted over a period of four weeks divided into two phases of two weeks each. During phase one the birds were divided into four groups. Three groups were offered a complete diet and a cereal on a free choice basis, while the other group was fed on a complete diet, which served as the control experiment. In the second phase of the experiment, the three choice fed groups were subdivided into two groups each. The subgroups were offered sole grains while the other groups continued with the treatments they received in the first phase. All the diets were fed *ad libitum*.

The results showed that there were no significant differences between treatments and the control with regard to feed intake, live weight gain, and carcass composition in the first phase of the experiment. During the second phase of the experiment, choice-fed birds had the highest live weight gain in the order of PF + maize > PF + sorghum > PF + wheat, but were not significantly different from the control group. Post-finisher plus maize fed birds had the highest live weight gain and their carcasses contained low body fat. Sole grain fed birds had lower live weight gains compared to the choice-fed and control groups in the order of wheat > maize > sorghum. The live weight of the latter groups changed by a small margin from the age of six to eight weeks. Of the three sole grain fed groups, the wheat fed group had the highest live weight gain and their carcass composition showed lower levels of body fat.

Financial analyses carried out at the end of the experiment showed that, the group choice-fed with maize had the lowest feed cost per live weight gain compared to the other choice-fed groups and the control group. Among the sole grain fed groups, the wheat fed group had the lowest feed costs per live weight gain.

It was therefore concluded, within the experimental errors, that choice feeding with any of the grains or feeding the grains solely to broilers that have reached slaughter weight, has no detrimental effect on the birds. The choice-fed birds performed better than the control group, while the sole grain fed birds performed as good as the control group. Both the choice feeding and sole grain feeding programs were economically efficient when compared to the complete diet feeding program, in terms of feed cost per live weight gain.

OPSOMMING

Vier weke oue braaikuikens, van albei geslagte, is gebruik om te bepaal of die tipe voerprogram, prestasie en winsgewendheid beinvloed. Prestasie is gemeet deur middel van voerinname, massa toename en karkassamestelling. Finansiële ontledings is gedoen om die mees doeltreffende voerprogram te bepaal in terme van voerkoste per lewende gewig toename.

Die voerprogramme gevolg is (i) 'n volledige rantsoen (ii) vrye keuse voeding met 'n volledige rantsoen en 'n graan en (iii) slegs 'n graan. Die volgende behandelings is gevolg:

1) Na-afrondings (NA) rantsoen as die kontrole
2) Na-afrondings (NA) rantsoen en gebreekte geelmielies
3) Na-afrondings (NA) rantsoen en koring (heel)
4) Na-afrondings (NA) rantsoen en sorgum (heel)
5) Gebreekte geelmielies
6) Koring (heel)
7) Sorgum (heel)

Die proefperiode van vier weke, is opgedeel in twee fases van twee weke elk. Gedurende die eerste fase, is die kuikens in vier groepe verdeel, waarvan drie 'n vrye keuse van 'n volvoer en 'n graan gekry het en die vierde groep slegs 'n volvoer gekry het. Gedurende die tweede fase is die drie groepe met vrye keuse, elk onderverdeel in twee groepe. Die sub-groepe het slegs graan ontvang, terwyl die ander groepe dieselfde behandeling gekry het as gedurende die eerste fase. Alle rantsoene is *ad libitum* gevoer.

In die eerste fase van die proef was daar geen betekenisvolle verskille in voer inname, massa toename en karkassamestelling, tussen die behandelings en kontrole groep nie. In die tweede fase het kuikens met keuse voeding, die hoogste massa toename gehad met NA + mielies > NA + sorgum > NA + koring. Die kuikens wat beide die na-afrondings rantsoen en mielies gekry het, het die hoogste massa toename gehad met die minste vet in die karkasse. Kuikens wat op slegs 'n graan rantsoen was, het laer massa toenames gehad as die kuikens op keuse voeding en die kontrole met koring > mielies > sorgum. Die lewende massa van laasgenoemde groepe het min verander vanaf ses tot agt weke ouderdom. Van die drie

groepe wat slegs graan gevreet het, het die koring-groep die meeste toegeneem in massa en het minder liggaamsvet gehad.

Finansiële ontledings aan die einde van die proef, het bepaal dat die groep van 'n vrye keuse met mielies, die laagste voerkoste per lewende massa toename gehad het in vergelyking met die kontrole en die ander groepe met vrye keuse. Die groep wat slegs koring gevoer is, het die laagste voerkoste per lewende massa toename gehad van die groepe wat slegs graan gevoer is.

Die gevolgtrekking kan gemaak word dat, binne eksperimentele foute, keuse voeding, ongeag die graansoort, of die voer van graan alleen, geen nadelige effek op braaikuikens het wat reeds slagmassa bereik het nie. Die kuikens wat keusevoeding gehad het, het beter presteer as die kontrole groep, terwyl die kuikens wat slegs graan gevreet het, net so goed soos die kontrole groep presteer het. In vergelyking met 'n volledige rantsoen voerprogram is beide keusevoeding en slegs graan voerprogramme finansieel doeltreffend.

DEDICATION

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Table of contents

List of tables

List of figures

List of abbreviations

Crude fat	CF
Crude protein	CP
Feed conversion ratio	FCR
Metabolisable energy	ME
Nitrogen free extract	NFE
Post-finisher	PF
Standard error	SE

1. INTRODUCTION

1.1 BACKGROUND

Poultry nutritionists have succeeded, to understand the nutrient requirements of poultry and ways of satisfying them. Establishing nutrient requirements for poultry relies heavily on the objectives set out for each specific class. For broilers, the general objective is the cost-effective production of edible meat. The specific objectives vary with the nature of the market to be served. Emphasis is on carcass composition in markets where specific demands for further processing, such as deboning and new product development, need to be met. In markets where sale of live chickens is important, more emphasis may be placed on carcass yield. Carcass yield is influenced by age and genetics while carcass composition could be manipulated through the diet given to the animal (Leeson and Summers, 1991).

In practice, broiler chickens are marketed over a range of ages e.g. 28 days as cornish to 70 days as roaster. It is advisable that farmers secure a market before their birds are ready for the market. Large companies often use vertical integration, that is, they co-ordinate forward and backward in the supply chain. In this way they work together to produce, raise and market their birds. In contrast, most small farmers are not integrated and often have insecure markets, except where they produce for a bigger company on contract. Farmers who fail to sell their birds upon reaching slaughter weight continue to feed them, albeit at a loss. In order to overcome this, a wide array of feeding programs may be followed.

Feeding programs used in the broiler industry include the use of feeds of different nutrient densities. Diets with low nutrient densities are used mainly to reduce feed costs while those of higher protein or amino acid contents are used for the production of carcasses with low fat content. Low-nutrient density feeding programs are most attractive when the prime consideration is live body weight, depending on the production goals of the farm. When emphasis is placed on lean meat production, feeding programs designed to maximise the intake of protein and specifically limiting amino acids in relation to energy, are of importance (Leeson and Summers, 1991). In this regard carcass weight and composition are used as production goals rather than live weight *per se* (Guenter and Campbell, 1995). There is a relationship between the number of calories of metabolisable energy in the diet and the percentage of protein necessary to balance the energy. If the diet contains more energy than protein, birds tend to accumulate more body fat. Another feeding program involves feed restriction or diet dilution, which affect mainly the growth pattern of the bird.

Complete diets are formulated based on nutrient requirements of an average bird. In a flock of chickens there are birds that have above average nutrient requirements and those with below average nutrient requirements. These differences in nutrient requirements are influenced by factors such as sex, age, performance objective[1] and individual variation (Belyavin, 1993). In such a case, below average birds will be over fed whilst above average birds will be under fed. When nutrients are underfed the maximum genetic potential for growth may not be achieved and efficiency of feed conversion will be poor. When they are overfed excess nutrients, protein, for example, will be deaminated and excreted. This is so because birds eat to satisfy their different nutrient needs. In contrast, choice feeding eliminates this variation in a flock by letting birds balance their own feed (Kleyn and Scharlach, 2000).

1.2 FREE CHOICE FEEDING

Choice feeding is a feeding system whereby an animal is offered a choice between two or more feedstuffs, e.g. a balancer or complete diet and a grain cereal. The grain is either fed in a separate feed trough or concurrently with other feed. Choice feeding may be viewed as a flexible feeding program that is able to meet a variety of needs of individual birds within a flock under different climatic conditions. According to Leeson and Caston, 1993, as well as Forbes and Covasa, 1995, choice feeding was a standard practice about 60 years ago for various reasons including economic and bird welfare.

The theory of choice feeding is based on the principle that animals select feed according to their nutrient requirements (Emmans, 1977; Hughes, 1984; Robinson, 1985; Rose and Kyriazakis, 1991; Forbes and Shariatmadari, 1994).

[1]Performance objective includes weight for age, feed conversion ratio, carcass yield, carcass composition and breast meat yield.

However, some studies have shown that feed intake in poultry is not only governed by specific nutrients. Cowan *et al*. (1978) compared intake of barley and wheat by egg-type pullets from 7 to 18 weeks of age and found that the birds consumed more wheat than barley although they are very similar in nutrient content. It was assumed that the low intake of barley was caused by its high content of ß-glucans. A similar study done by Rose and Njeru (1989) using barley treated with ß-glucanase showed an increase in barley intake by choice fed broilers. Classen *et al*. (1988) alternatively, found that older birds could successfully use barley because they seemed to be more tolerant of the ß–glucans. It might be said that these results show that nutrient requirements are not the only factor that influences diet selection; palatability is also an important factor. Hughes (1984) supports this idea and adds that the texture of the diet should also be taken into account.

1.2.1 Choice feeding of whole grain

Choice feeding of whole grains has tremendous financial advantage (Munt *et al*., 1995; Oliver, 1996; Olver and Joker, 1997), particularly for small scale farming because it saves the cost of grinding and mixing in cases where farmers mix their own feed (Rose *et al*., 1986; Anonymous, 1987). If bought conventional feed is used the saving can be significant if the farmers have access to inexpensive grains.

Oliver (1996) determined differences in the cost of feeding commercial finisher pellets as opposed to choice feeding whole maize or whole sorghum plus pelleted concentrate. Three weeks old broilers were used until they were 8 weeks of age. The cost of choice feeding when maize was purchased at R460/tonne and sorghum at R420/tonne was R873 and R832 per tonne respectively, whilst feeding finisher pellets cost R1200 per tonne. This study indicates that large savings could be obtained by choice feeding.

Although choice feeding can be economically efficient, there are also some extra costs to be set against the savings, these include new installation costs. Particularly the automatic equipment needed to control the quantity of grain provided if the grain is going to be fed concurrently with a protein concentrate or complete diet. On the other hand, choice feeding will incur extra costs of separate troughs or changing the design of the trough. Nevertheless, the reduction in costs attributed to grinding, mixing and pelleting counterbalance the extra costs involved and leads to a higher profit margin than can be achieved with the standard commercial diet (Forbes and Covasa, 1995).

Whole grain stimulates feed intake (Robinson, 1985; Oliver, 1996). This depends on the acceptability of the grain to the birds. Certain grains are more acceptable than others. Oliver (1996) offered whole maize and sorghum to three week-old broilers and found that they consumed more sorghum than maize. He claimed that it was influenced by grain size. To support this, Forbes and Covasa (1995) found no difference in the acceptability of sorghum or wheat to broilers.

Whole grain is coarse and thus has less surface area. It is therefore retained in the proventriculus for a longer period of time (Anonymous, 1987; Kleyn and Scharlach, 2000). Consequently, it is exposed to the digestive enzymes of the proventriculus for a longer period resulting in an increased feed conversion and consequent increased growth rate. Contrary to this, some researchers report discouraging results on feed conversion ratio (FCR) (Anonymous, 1987; Olver and Jonker, 1997). From the study done by Anonymous (1987), it was found that including whole wheat at levels of 2% to 35% when the birds were 14 days to 29 days and older respectively, resulted in a reduction of FCR by 0.02 – 0.03 (g/g of feed) and a loss in body weight of 20 to 30g.

Although some researchers (Forbes and Covasa, 1995) report that mixing whole grain with feed results in growth and carcass quality as good as that of birds raised on commercial grower. Kleyn and Scharlach (2000) argue that it is the digestive tract of the bird that increases in size, not the carcass *per se*, resulting in reduced carcass yield because the digestive tract forms a large portion of the total live mass.

Several experiments have shown that choice feeding grains as a source of energy results in an increase in body fat. In Anonymous (1987)'s study choice fed birds were found to contain more abdominal fat. Also, Olver and Jonker (1997) offered diets either mixed as pellets or mash or on a free choice basis to 21 to 56 days old male broilers to determine carcass composition among other things. They found that choice fed broilers receiving whole grains had higher carcass fat while the higher protein diets resulted in a lower carcass fat than those fed the pelleted control diet. Table 1.1 shows the results.

Table 1. 1 Carcass characteristics of broilers from 21 to 42 d of age (Olver and Jonker, 1997)

Diet	Moisture (g/kg)		Fat (g/kg)		Protein (g/kg)		Ash (g/kg)	
Age	42 d	56 d	42 d	56 d	42 d	56 d	42 d	56 d
Pelleted finisher (Control)	644.3	631.7	431.9	480.6	491.0	453.8	63.9	64.2
Mash finisher	658.7	647.3	407.4	449.8	512.5	472.1	63.9	63.8
50/50 sorghum/protein conc.	690.3	682.7*	351.5	335.7**	551.1	571.9**	71.3	74.7
50/50 maize/protein conc.	682.0	677.0*	359.5	335.1**	545.8	566.4**	72.1	72.0
Whole maize + pelleted conc.	653.7	635.3	416.4	470.0	503.0	463.8	65.9	64.8
Mash maize + pelleted conc.	657.3	648.3	415.4	428.0	504.5	488.8	67.6	63.4
Whole maize + mash conc.	653.3	645.7	423.2	468.9	492.9	565.6	64.0	61.6
Mash maize + mash conc.	657.0	649.0	417.4	428.4	495.8	491.0	75.8	64.9
Whole sorghum + pelleted conc.	651.7	636.0	423.8	464.9	493.1	468.9	63.4	63.1

Means significantly different from the control $^{**}P < 0.01$; $^{*}P < 0.05$.

Forbes and Covasa (1995) questioned the legality of mixing grains with a complete diet. This concern arises because the legislation covering animal feedstuffs prohibits feed manufacturers from mixing untreated cereals with compound feed because of the risk of transmission of disease. It also covers medicated animal feedstuffs, claiming that birds eating less compound feed will receive less of any medication contained therein.

Conversely, Kleyn and Scharlach (2000) argue that feeding unprocessed whole grain to birds ensures that they receive all the nutrients in the grain that could have been affected by feed processing. They report that birds obtain about 5 to 6% more energy from whole grain than from processed diet. Even so, feed processing is also beneficial in that it destroys some antinutritional or toxic factors (Bourdon *et. al.*, 1987). For example, *Salmonellae* have been isolated from most raw materials used in broiler feed such as wheat and it was proved that it could be controlled by heat treatment (Belyavin, 1993).

Following the concerns raised on the safety of untreated grains, more complex and comprehensive computer-monitored and computer-controlled feeding systems have recently been developed. These systems accurately control the proportion of whole grain in order to match the birds' potential and actual growth (Forbes and Covasa, 1995). They also have special equipment for the acid treatment of grain against harmful organisms.

1.2.2 Factors that influence diet selection of choice fed birds

a) Presentation of feed to animals

The first major step into practical application of choice feeding was directed towards developing appropriate systems in which both feeds could be offered separately. When various feedstuffs are offered in separate containers the design of the trough needs to be considered. There are different systems depending on whether it is for full-choice feeding or semi-choice feeding and the type of housing i.e. cage or floor housed birds (Forbes and Covasa, 1995).

One such system for cage-housed birds on full-choice feeding was developed by Tauson and Elwinger (1986) using two narrow flat chain feeders, one distributing a mash concentrate and the other distributing whole grain. They found that choice feeding from flat feeders is feasible in small experiments and thus proposed that more studies be done before similar systems could be used commercially.

In addition to the design of feed troughs, Summers and Leeson (1979) as well as Hughes (1984) found that colour and position of food in the feed trough are also important with regard to diet presentation.

b) Type, form and the nutritive value of grain

The type of grain used in free choice feeding has an effect on feed intake and performance (Munt *et al*. 1995). However, Rose *et al*. (1986) found no differences in performance but only in intake. They assumed that the higher consumption of some grains than other grains was associated to lower metabolisable energy content of the grain.

Since birds use energy and protein as key nutrients in regulating their intakes, they are able to adjust their grain intake when offered a free choice between grains and protein concentrate

(Forbes and Covasa, 1995). For this reason, the type or form of grain used in free choice feeding does not influence production performance of birds but influences to some extent, the protein concentrate intake, which may lead to inefficient utilisation of protein and other nutrients.

c) Physical form of diet

The physical form of a diet influences gizzard development (Forbes and Covasa, 1995). Olver and Joker (1997) choice fed 21 to 56 d old male broilers on maize or sorghum with protein concentrate and found that birds choice fed whole grains had larger gizzards compared to the control that was fed pelleted finisher. Munt *et al.* (1995) also reported that broilers choice fed either whole wheat or sorghum with a concentrate mix had heavier gizzards.

Modern birds are fed predominantly on low-fibre diets without access to grit as a result, their gizzards are small and the proventriculi may be dilated (Forbes and Covasa, 1995). These results in food passing through the stomach partially digested and arriving in the duodenum still in a particulate form, which might increase the incidence of coccidiosis. Experiments have shown that high fibre diets, such as whole wheat, activate the gizzard and reduce oocyst excretion thus reducing the incidence of coccidiosis (Covasa and Forbes, 1993a). However, the mechanism by which an active gizzard reduces the incidence of oocysts is not fully understood.

Whole grain or pelleted feed increases the ability of birds to grind food and ease digestion (Forbes and Covasa, 1995). These researchers offered broilers whole wheat and a high-protein feed. The birds selected a higher proportion of whole wheat when grit was available. It was assumed that it is because they were better able to grind it in the gizzard in which the grit is stored for this purpose. When access to grit was later denied there was a reduction in the intake of the whole grain.

d) Prior exposure

Birds may benefit from a period of adjustment or exposure to choice feeding (Covasa and Forbes, 1995). If birds are exposed to grains before subsequent choice feeding, they familiarise themselves with the appearance and metabolic effects of the grains and can eventually make nutritionally wise selection. Such birds are reported to perform better when compared to those directly put on choice feeding.

Mastika and Cumming (1981) showed that the age at which chickens are introduced to choice feeding has no effect. Contrary to this finding, Covasa and Forbes (1993b) choice fed day old chicks on commercial starter crumbs with whole wheat until they were 4 weeks old and then grower pellets and whole wheat until they were 7 weeks old. Three groups were exposed to choice feeding for four days prior to the actual experiment at the age of 1, 2 and 3 weeks, by offering them crumbs and wheat either on alternate days or in a choice, except for one group that was directly introduced to choice feeding. The following table shows results of the performance of the birds.

Table 1.2 Feed intake (g/bird) and Body weight (g) (Covasa and Forbes, 1993b)

Week	Group	1	2	3	4
5	Pellets	$81.3^{a} \pm 4.2$	$82.7^{a} \pm 3.9$	$85.8^{a} \pm 4.7$	$93.3^{a} \pm 4.9$
	Wheat	$1.5^{c} \pm 0.2$	$8.7^{ab} \pm 1.6$	$7.9^{b} \pm 1.2$	$12.1^{a} \pm 1.5$
	Body weight	$673^{a} \pm 12.3$	$646^{a} \pm 14.4$	$635^{a} \pm 23.0$	$576^{b} \pm 40.3$
6	Pellets	$116.8^{a} \pm 4.6$	$104.4^{a} \pm 5.1$	$107.5^{a} \pm 5.3$	$103.7^{a} \pm 4.3$
	Wheat	$2.8^{b} \pm 1.1$	$12.2^{a} \pm 2.4$	$5.8^{b} \pm 1.4$	$13.8^{a} \pm 2.1$
	Body weight	$886^{a} \pm 42.5$	$943^{a} \pm 31.5$	$957^{a} \pm 42.9$	$902^{a} \pm 41.2$
8	Pellets	$141.7^{a} \pm 4.2$	$127.4^{bc} \pm 5.3$	$117.5^{c} \pm 5.8$	$132.1^{ab} \pm 4.3$
	Wheat	$4.4^{b} \pm 1.4$	$10.6^{a} \pm 2.2$	$8.6^{ab} \pm 2.5$	$13.0^{a} \pm 2.1$
	Body weight	$1275^{a} \pm 45.5$	$1209^{a} \pm 51.2$	$1288^{a} \pm 53.3$	$1215^{a} \pm 61.0$

^{a,b,c} Values in the same row with unlike superscripts were significantly different ($P < 0.05$)

Based on the results presented in the above table, these researchers concluded that both age at which chicks were introduced to choice feeding and the learning method significantly affected feed intake with birds that had prior exposure having significantly higher body weight during the first week, but not at the end of the experiment. They then suggested, in their later studies, that in order to achieve optimum biological performance, choice feeding should be introduced before sexual maturity in hens and from the first week of life in broilers (Forbes and Covasa, 1995).

e) Training

Covasa and Forbes (1994) investigated whether or not birds needed a training period before introducing them to the choice of grain and a conventional feed using wheat and a complete diet. They found that birds exposed directly to choice feeding obtained the best results and concluded that training is not necessary. They later embarked on a similar experiment (Forbes and Covasa, 1995) where they trained day-old birds by accustoming them to whole grains. From this work however, training appeared to have benefits at later stages of growth by improving the ability of the birds to select foods to meet nutrient requirements, which suggested that training is necessary.

Training the birds to distinguish between the properties of the food can be achieved in different ways. The bird can be exposed to the grain a few hours each day or sole access to the grain on alternate days. This gives good dietary selection once choice feeding is begun (Kyriazakis *et al.*, 1990).

However, these techniques cannot be used in the case of choice feeding whole grains for several reasons. Firstly, although there are obvious visual differences between the feed offered, the digestive tract of birds fed with whole grain has to adapt by undergoing physical changes in order to facilitate digestion. Secondly, birds can avoid eating the grain by learning to eat only when conventional feed is available (Pinchasov *et al.*, 1985; Rose *et al.*, 1994).

f) Social interactions

Group housed animals are more successful in selecting a diet that meets their requirements than those caged individually (McDonald *et al.*, 1963; Adret-Hausberger and Cumming, 1987). Larger variations had been noticed between individuals in a group, but there are always slow learners with a higher number in broilers than in hens housed in groups (Covasa and Forbes, 1994). Rose *et al.* (1986) found no difference in diet selection in broilers kept in groups of 20, 40 and 60. Covasa and Forbes (1994) found significant differences between single-caged birds and pairs of birds in terms of their grain consumption, despite the fact that the design of the cage allowed the individually caged birds to see each other. Forbes and Covasa (1995) suggest that birds need to be in groups of at least eight.

Nicol and Pope (1993) suggest that using experienced birds as 'teachers' could accelerate the process of learning since learning is influenced by the presence and behaviour of experienced birds. On the contrary, Covasa and Forbes (1994) found no difference between groups of birds with or without a 'teacher'. They therefore suggested that it is not necessary to use experienced birds as teachers because simply putting the birds together encourages grain intake.

Dove (1935) reports that certain individuals in a group of birds constantly initiate feeding such that the whole group tend to develop a bias feeding behaviour. This bias behaviour could not be observed in larger groups of birds, but was noticed in smaller experimental groups. This is because variability between birds is a common feature of choice feeding experiments. Large groups tend to have a small variability while smaller groups have larger variability. In order to minimise the effect of variability, using a larger group of birds within a particular treatment is recommended because performance is measured based on the group.

Generally, previous studies show that acceptable performance could be achieved with birds that are choice fed balanced diets and whole grain cereals such as wheat, sorghum and maize (Cowan *et al.*, 1978; Summers and Leeson, 1978; Rose *et al.*, 1986; Anonymous, 1987; Oliver, 1996). However, some studies show no significant difference in performance between choice fed birds and birds fed on conventional feed (El-Husseiny and Ghazalah, 1980). It may therefore be said that of all the benefits that may be achieved from choice feeding, the main advantage appears to be savings on feed costs.

1.3 Aim Of Study

The objective of this study was to compare the performance and profitability of broilers fed with the following:

a) Post-finisher diet as a control,

b) Post-finisher plus cracked yellow maize,

c) Post-finisher plus whole wheat,

d) Post-finisher plus whole sorghum,

e) Cracked yellow maize,

f) Whole wheat or

g) Whole sorghum.

The experiment was based on the assumption that there will be no significant differences in performance between groups of birds fed post-finisher, choice feeding or grain. The parameters measured included feed intake, growth and carcass composition. The financial analysis of the study was based on the assumption that choice feeding or feeding grain only as opposed to post-finisher after birds have reached slaughter weight will be economically efficient.

2. MATERIALS AND METHODS

The study was conducted on a flock of mixed sex four-week-old broilers at the Mariendahl Poultry Experimental Farm of the University of Stellenbosch. The data obtained was used to determine the effects of either feeding a complete diet, choice feeding or feeding of grains solely on the performance of broilers. The parameters measured include feed intake, growth and carcass composition. Financial analysis was done on each treatment to determine which of the feeding programs reduces feed costs.

2.1 EXPERIMENTAL PROCEDURES

2.1.1 Test samples

The post-finisher diet was purchased from a commercial feed company and was used as a control. Three types of grains were purchased from a co-operative.

Table 2.1 Description of treatments allocated to birds

Group	Treatment
A	Post-finisher
B	Post-finisher + Cracked yellow maize
C	Post-finisher + Whole wheat
D	Post-finisher + Whole sorghum
E	Cracked yellow maize
F	Whole wheat
G	Whole sorghum

2.1.2 Birds and management

Two hundred and eighty broilers from a commercial hatchery in South Africa were reared on a complete diet until they were 28 days of age. The diet comprised of a starter mash fed from day 1 to day 14 and finisher pellets fed from day 14 to day 28. For this period the birds were allowed *ad libitum* access to feed and water. At the end of this period they were weighed in groups of ten and the mean body weight was 1.06 kg ± 0.0391. The birds were randomly allotted to 28 wire pullet-rearing cages, each cage holding ten birds.

a) Housing

The pullet rearing cages were placed in an environmentally controlled room where artificial lighting of 24 hours was maintained. Room temperature was maintained at 21°C for the duration of the experiment.

b) Feed consumption

Each cage was equipped with a feed trough suspended in front of the cage and two nipple drinkers suspended at the rear of the inside of the cage. The feed troughs were partitioned transversely into two equal halves. For the post-finisher (PF) and grain-only treatments, feed was placed in both compartments. For choice feeding the grain and post-finisher were placed in different compartments. Weekly feed intake was accurately measured and recorded.

c) Diets

The period of the experiment was four weeks divided in two phases of two weeks each. Figure 2.1 shows the design of the phases. Phase one had four treatments: Post-finisher only, post-finisher plus cracked maize, post-finisher plus whole wheat and post-finisher plus whole sorghum. The control was administered to four replicate cages of ten chickens each while the other treatments were administered to eight replicate cages of ten chickens each. Phase two had seven treatments: Post-finisher only, post-finisher plus cracked maize, post-finisher plus whole wheat, post-finisher plus whole sorghum, cracked maize only, whole wheat only and whole sorghum only. In this phase all the diets were administered to four replicate cages of ten chickens each. All the diets were fed *ad libitum*.

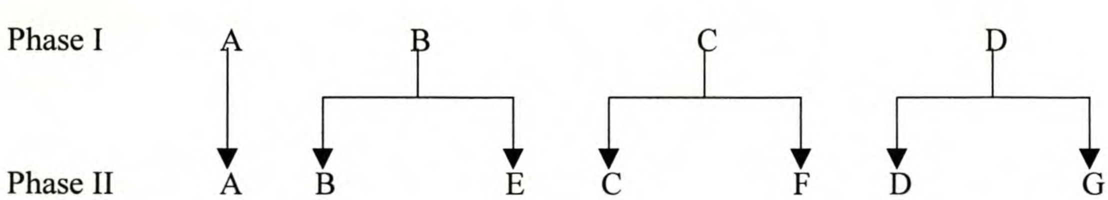

Figure 2.1 Design of phases

2.1.3 Trial procedure

The broilers were directly allocated to choice feeding at four weeks of age. Feed intake was measured every seven days. Post-finisher intake was measured separate from grain intake for the purpose of determining the proportions at which the two feedstuffs were consumed.

At the beginning of the trial the birds were weighed. The average body weight per bird was 1.06 kg ± 0.0391. This was done so that the weight gain of the birds could be monitored in the subsequent weeks. The birds were weighed every seventh day thereafter.

At the end of each phase two birds from one replica of each treatment were starved for four hours, weighed and then slaughtered by breaking their necks to prevent any loss of blood. They were defeathered by hand, using water of 60°C temperature. The plucked carcasses were weighed to determine the weight of the feathers by difference and then stored at -20°C for later use. The two frozen carcasses from each replica were minced, pooled, mixed thoroughly and sampled for carcass composition analysis.

2.1.4 Handling of the samples

A hammer mill, with 1mm screen, was used to grind the feed samples for chemical analysis. The carcasses were cut into smaller pieces before they could be minced so as to fit into the grinder. An auger-type meat grinder was used to mince the pieces of the carcass to ensure a homogenous sample. The mince was frozen and stored in vacuum-sealed packets at -20°C until required for analysis.

2.1.5 Analytical procedures

Samples of grains and carcasses were analysed using standard laboratory methods according to the Association of Official Analytical Chemists (AOAC, 1990). The feed samples were analysed for nitrogen (N) for crude protein (GP), calcium (Ca), phosphorus (P), ether extract (EE) for crude fat (CF), crude fibre, dry matter (DM) and ash contents. Nitrogen free extract (NFE) percentage was also determined in the feed samples. Metabolisable energy (ME_n) values used for the feed samples were obtained from the National Research Council (NRC) tables (NRC, 1994). The carcasses were analysed for crude fat, crude protein, crude fibre, dry matter and ash contents. The nitrogen (N) content was determined by the macro-Kjeldahl method and the protein value calculated as N x 6.25. The percentage of NFE was found by difference using the equation (Ensminger, 1992):

$$\text{NFE} = 100 - (\%\ \text{Ash} + \%\ \text{Crude fibre} + \%\ \text{Crude fat} + \%\ \text{Crude protein}) \qquad \text{eq. (1)}$$

2.1.6 Statistical analysis

Data from the experiment were subjected to General Linear Models (GLM) procedure of Statistical Analysis System (SAS, 1992) with the main effects being body weight gain and feed intake. All statistical comparisons were considered significant at $P<0.05$.

2.1.7 Economic analysis

The financial analysis of the experiment was done to determine the economic efficiency of choice feeding or feeding grain as an alternative to feeding a complete diet to broilers after they have reached slaughter weight. For this analysis it was assumed that other production costs remained constant and only feed cost would vary. Feed cost, used to calculate cost per live weight gain, was determined by multiplication of the feed price by the quantity consumed by a bird. The domestic annual average price for the year 2000 of the feedstuffs was used.

3. RESULTS AND DISCUSSION

The results obtained from the experiments are presented and discussed in this chapter. Results from chemical analyses of the feedstuffs are presented in Table 3.1. The results on the performance of birds collected in phase one of the experiments are presented first and results from the second phase are presented last. These results are discussed according to the different feeding programs.

3.1 RESULTS

3.1.1 Feed composition

Table 3.1 Chemical compositions of the feed samples (Dry matter basis)

	Post-Finisher	Maize	Wheat	Sorghum
DM %	88.44	88.11	87.20	89.49
Moisture %	11.56	11.89	12.80	10.51
Ash %	2.87	1.46	1.52	2.00
Crude Fibre %	3.29	2.20	2.22	2.16
Crude Fat %	5.70	3.64	3.31	3.20
Crude protein %	17.00	7.52	12.78	9.81
ME_n MJ/kg	13.30	14.02	13.06	13.44
Calcium %	0.85	0.01	0.01	0.01
Phosphorus %	0.40	0.25	0.25	0.25
NFE %	71.14	85.62	80.59	84.48

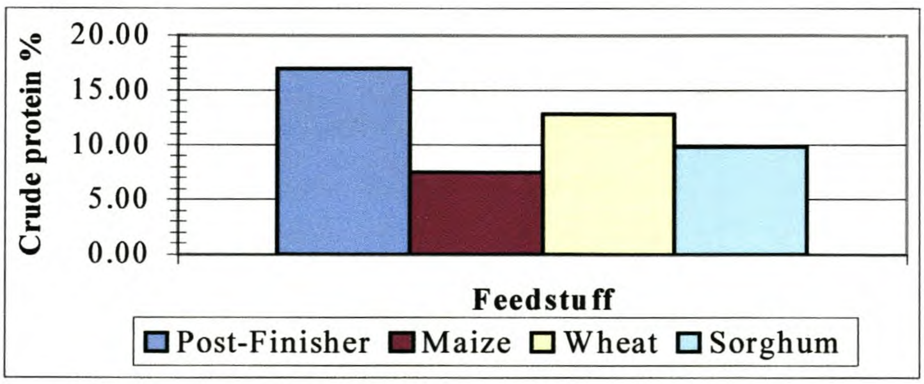

Figure 3.1 Crude protein content in feedstuffs

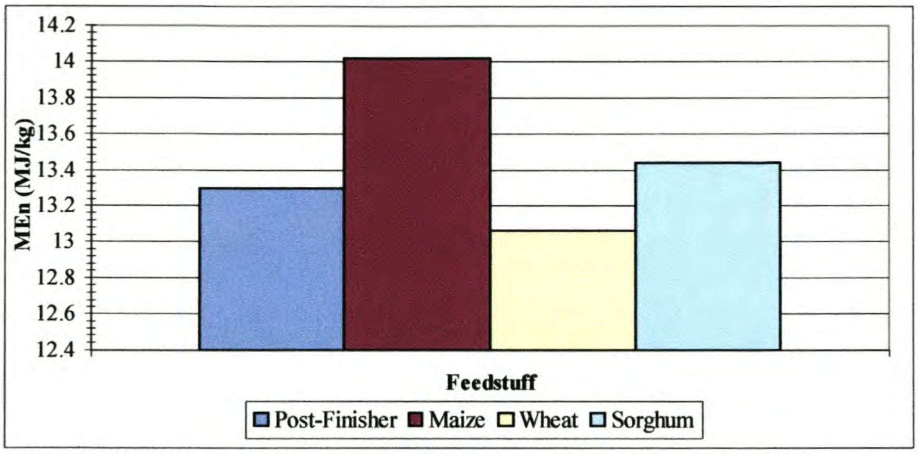

Figure 3.2 Metabolisable energy (ME_n) in feed

Post-finisher appeared to have the highest crude protein and maize the lowest as shown in Figure 3.1. Maize seemed to have the highest and wheat the lowest metabolisable energy as shown in Figure 3.2. Maize appeared to have the highest and post-finisher the lowest nitrogen free extract[2] (NFE).

3.1.2 Performance of birds during phase one

a) Feed intake

The total feed intake for phase one was analysed statistically using SAS. Post-finisher intake was measured separate from grain intake for the purpose of determining the proportions at which the two feedstuffs were consumed. These feed intakes are shown in Figure 3.3.

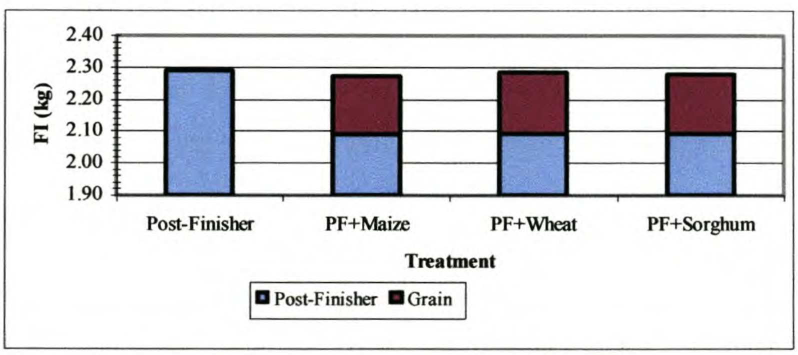

Figure 3.3 Feed Intake of broilers at 5 – 6 weeks of age

[2] Nitrogen-free extract (NFE) is a group of substances consisting of starches, sugars, dextroses, pentosans, organic acids, phytin, lignin, and other substances (Ewing, 1951). In cereals nearly all of the NFE is starch.

Results presented in Table 3.2 show a significant difference in post-finisher intake ($P < 0.01$) with the control group having consumed the highest amount. It also shows a significant difference in grain intake ($P < 0.01$), but this was mainly between the control group (which was not offered any grains) and the choice fed treatments. No significant differences were found between the treatments with regard to total feed intake as well as feed efficiency.

b) Crude protein intake

Statistical analyses showed no significant difference in protein intake and conversion ratio among the treatments (Table 3.2).

c) Metabolisable energy intake

Statistical analyses showed no significant differences in ME_n intake as well as ME_n conversion between the treatments (Table 3.2).

d) Fat intake

There were no significant differences in fat intake between the treatments (Table 3.2).

e) Live weight gain

The birds were weighed weekly and the total weight gain over a two-week period starting from the inception of the experiment was considered. Post-finisher plus wheat fed birds seemed to have gained more weight, while the control group appeared to have gained less weight (Table 3.2). However, statistical analyses show that the differences in weight gain were insignificant.

Table 3.2 Performance of six weeks old broilers

Variable	Post-finisher	PF + Maize	PF + Wheat	PF + Sorghum
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Initial live weight, kg	1.090 ± 0.0277	1.060 ± 0.1681	1.050 ± 0.1681	1.071 ± 0.1681
Live weight wk6, kg	2.064 ±0.0425	2.060 ± 0.0300	2.045 ± 0.0300	2.050 ± 0.0300
Mean wt gain, kg/2wks	0.974 ± 0.0251	0.997 ± 0.0178	0.998 ± 0.0178	0.976 ± 0.0178
FeedIntake per bird/2wks				
Post-finisher, kg	2.293^{A} ± 0.0292	2.089^{B} ± 0.0207	2.093^{B} ± 0.0207	2.093^{B} ± 0.0207
Grain, kg	0.000^{B} ± 0.0113	0.183^{A} ± 0.0080	0.192^{A} ± 0.0080	0.186^{A} ± 0.0080
Total FeedIntake, kg	2.293 ± 0.0328	2.272 ± 0.0232	2.285 ± 0.0232	2.278 ± 0.0232
CP intake, g/kg feed	159.180 ± 0.0054	162.412 ± 0.0038	166.302 ± 0.0038	164.179 ± 0.0038
Fat intake, g/kg feed	53.493 ± 0.0018	55.418 ± 0.0012	55.132 ± 0.0012	54.780 ± 0.0012
ME_n intake, MJ/kg	0.305 ± 0.0047	0.304 ± 0.0033	0.304 ± 0.0033	0.303 ± 0.0033
Feed efficiency				
Feed conversion ratio	2.357 ± 0.0378	2.281 ± 0.0267	2.292 ± 0.0267	2.337 ± 0.0267
Protein conversion ratio	0.376 ± 0.0060	0.370 ± 0.0043	0.382 ± 0.0043	0.384 ± 0.0043
Energy conversion ratio	0.305 ± 0.0044	0.304 ± 0.0039	0.304 ± 0.0039	0.303 ± 0.0039

^{a,b,c} Values in the same row with unlike superscripts were significantly different (P < 0.05)

^{A,B,C} Values in the same row with unlike superscripts were significantly different (P < 0.01)

f) Carcass composition

Chemical analyses of the carcasses of birds slaughtered at the age of six weeks are given in Table 3.3.

Table 3.3 Carcass compositions of birds slaughtered at six weeks of age (Dry matter basis)

	Post-Finisher	PF + Maize	PF + Wheat	PF + Sorghum
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
DM %	36.45 ± 0.274	35.92 ± 0.465	37.30 ± 0.217	38.81 ± 0.311
Moisture %	63.55 ± 0.274	64.08 ± 0.465	62.70 ± 0.217	61.19 ± 0.311
Ash %	8.54 ± 1.686	7.21 ± 0.249	7.19 ± 0.450	7.50 ± 0.913
Crude protein %	50.65 ± 0.956	49.74 ± 0.652	50.43 ± 0.834	45.52 ± 2.402
Crude fat %	41.55 ± 2.480	45.74 ± 3.392	46.40 ± 0.459	49.92 ± 3.277

i) Crude protein in carcass

Carcasses of the control group appeared to contain the highest crude protein followed by the post-finisher plus wheat fed group, while birds fed on post-finisher plus sorghum seemed to contain the lowest crude protein (Table 3.3).

ii) Crude fat in carcass

According to Table 3.3, birds fed post-finisher plus sorghum appeared to have the highest body fat. The control seemed to have the lowest body fat. There was no noticeable difference between post-finisher plus maize and post-finisher plus wheat fed birds.

3.1.3 Performance of birds during phase two

Results of the performance of birds at eight weeks of age are shown in Table 3.4.

a) Feed intake

Post-finisher intake was measured separate from grain intake in order to determine the proportions at which the two feedstuffs were consumed. These feed intakes are shown in Figure 3.4.

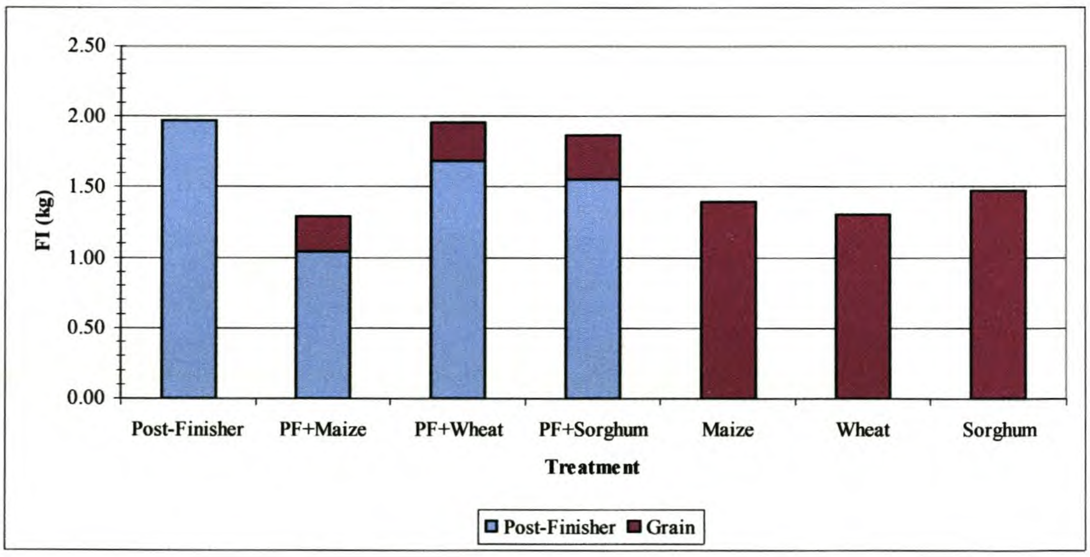

Figure 3.4 Feed Intake of broilers at 7 – 8 weeks of age

Post-finisher intake was significantly different ($P < 0.01$) between the treatments. The control group had the highest post-finisher intake. From the t-test, it was noticed that among the choice-fed groups the post-finisher plus wheat fed group consumed the most post-finisher but it was not significantly different from the group fed post-finisher plus sorghum (Table 3.4). These two groups, however, consumed significantly more post-finisher than the post-finisher plus maize fed birds. The t-test also showed that the choice-fed groups consumed significantly less post-finisher in comparison with the control.

Table 3.4 Performance of birds aged eight weeks

Variable	Post-Finisher	PF + Maize	PF + Wheat	PF + Sorghum	Maize	Wheat	Sorghum
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Live weight wk6, kg	2.064 ± 0.0425	2.055 ± 0.0300	2.045 ± 0.0300	2.047 ± 0.0300	2.055 ± 0.0300	2.045 ± 0.0300	2.047 ± 0.0300
Live weight wk8, kg	2.873^{A} ± 0.1092	2.977^{A} ± 0.1092	2.806^{A} ± 0.1092	2.946^{A} ± 0.1092	2.274^{BC} ± 0.1092	2.462^{B} ± 0.0573	2.141^{C} ± 0.1092
Mean wt gain, kg/2wks	0.809^{A} ± 0.0915	0.928^{A} ± 0.0915	0.819^{A} ± 0.0915	0.853^{A} ± 0.0915	0.212^{BC} ± 0.0915	0.360^{B} ± 0.0915	0.140^{C} ± 0.0915
Feed intake per bird/2wks							
Post-Finisher, kg	1.969^{A} ± 0.0928	1.038^{C} ± 0.0928	1.684^{B} ± 0.0928	1.559^{B} ± 0.0928	0.000^{D} ± 0.0928	0.000^{D} ± 0.0928	0.000^{D} ± 0.0928
Grain, kg	0.000^{C} ± 0.0702	0.255^{B} ± 0.0702	0.269^{B} ± 0.0702	0.309^{B} ± 0.0702	1.394^{A} ± 0.0702	1.307^{A} ± 0.0702	1.476^{A} ± 0.0702
Total Feed intake, kg	1.969^{A} ± 0.1325	1.293^{B} ± 0.1325	1.953^{A} ± 0.1325	1.867^{A} ± 0.1325	1.394^{B} ± 0.1325	1.307^{B} ± 0.1325	1.476^{B} ± 0.1325
CP intake, g/kg feed	170.137^{A} ± 0.0194	151.585^{B} ± 0.0194	164.362^{A} ± 0.0194	158.007^{A} ± 0.0194	75.323^{C} ± 0.0194	127.774^{B} ± 0.0194	98.238^{BC} ± 0.0194
Fat intake, g/kg feed	56.882^{A} ± 0.0064	52.591^{A} ± 0.0064	53.712^{A} ± 0.0064	52.491^{A} ± 0.0064	36.585^{B} ± 0.0064	32.899^{C} ± 0.0064	30.488^{C} ± 0.0064
ME intake, MJ/kg	0.262^{A} ± 0.0204	0.185^{B} ± 0.0204	0.259^{A} ± 0.0204	0.249^{A} ± 0.0204	0.195^{B} ± 0.0204	0.171^{B} ± 0.0204	0.198^{B} ± 0.0204
Feed efficiency							
Feed conversion ratio	2.492 ± 4.9759	1.414 ± 4.9759	2.389 ± 4.9759	2.184 ± 4.9759	19.711 ± 4.9759	3.958 ± 4.9759	10.999 ± 4.9759
Protein conversion ratio	0.424 ± 0.3772	0.214 ± 0.3772	0.392 ± 0.3772	1.345 ± 0.3772	0.482 ± 0.3772	0.506 ± 0.3772	1.079 ± 0.3772
Energy conversion ratio	0.262^{A} ± 0.0177	0.174^{C} ± 0.0177	0.259^{A} ± 0.0177	0.249^{AB} ± 0.0177	0.195^{C} ± 0.0177	0.171^{C} ± 0.0177	0.198^{BC} ± 0.0177

^{a,b,c} Values in the same row with unlike superscripts were significantly different ($P < 0.05$)

^{A,B,C} Values in the same row with unlike superscripts were significantly different ($P < 0.01$)

The difference in grain consumption between the treatments was statistically significant ($P < 0.01$) (Table 3.4). The t-test showed that the difference was between the choice fed groups and the sole grain fed groups with sole grain fed birds having consumed more grain. Table 3.4 however, showed that there was no significant difference between the groups within the same feeding program.

There was a significant difference in total feed intake ($P < 0.01$). The control group had the highest total feed intake while the post-finisher plus maize group had the lowest (Table 3.4). In general, the sole grain fed groups had a low total feed intake compared to the other treatments with the exception of the group that was fed post-finisher plus maize.

b) Crude protein intake

Statistical analyses showed significant differences in protein intake among the treatments ($P < 0.01$) (Table 3.4). The control group had the highest crude protein intake in comparison to the other treatments. Post-finisher plus wheat fed birds had the highest crude protein intake compared to the other choice-fed and sole grain fed groups. There was no significant difference between the treatments with regard to protein conversion ratio.

c) Metabolisable energy intake

Statistical analyses showed no significant difference in metabolisable energy intake among the treatments (Table 3.4). The ME conversion ratios were significantly different ($P < 0.01$). The post-finisher plus maize fed group had the best ME conversion ratio of the choice-fed groups and in comparison with the control, while the wheat fed group had the best ME conversion ratio of the sole grain fed groups. The t-test showed however that the differences in ME conversion ratios between the sole grain fed groups were not significant but were significantly different from the control group.

d) Fat intake

There were significant differences between the treatments with regard to fat intake ($P < 0.01$) (Table 3.4). Maize and wheat choice-fed groups had the highest fat intake among the choice fed groups, which were insignificantly different from the control group. Although the sorghum choice-fed group had the lowest fat intake, it was also not significantly different from the control group. Among the sole grain fed groups, the maize fed group had the highest fat intake. The t-test showed that the fat intake of the wheat fed group was not significantly different from that of the sorghum fed group. It also showed that the sole grain fed groups had fat intakes significantly lower than that of the control group.

e) Live weight gain

Statistical analyses showed a significant difference in live weight gain ($P < 0.01$) between the treatments (Table 3.4). Post-finisher plus maize fed birds gained the most weight during the last phase of the trial, followed by the post-finisher plus sorghum group. Post-finisher plus wheat fed group gained the least live weight among the choice-fed treatments. The t-test however showed that the differences in live weight gains between these groups were not significant and that they were not significantly different from the control group either. Among the sole grain fed groups, the wheat fed group gained the most weight, but was not significantly different from the maize fed group. The sorghum fed group gained the least weight, but was also not significantly different from the group fed on maize only. Nonetheless, the weight gains of the sole grain fed groups were significantly lower than those of the choice-fed and control groups according to the t-test.

f) Carcass composition

Results from chemical analyses of carcasses of birds slaughtered at the age of six weeks are presented in Table 3.5.

i) Crude protein in carcass

Carcasses of birds fed post-finisher plus wheat appeared to have the highest crude protein and those of birds fed sorghum only, the lowest compared to the control group. The sole maize fed group appeared to contain the highest crude protein among the sole grain fed groups, which also seemed higher than that of the control.

ii) Crude fat in carcass

According to Table 3.5, carcasses of birds fed sorghum solely, appeared to contain the highest body fat, while those fed post-finisher plus wheat seemed to have the lowest body fat in comparison to the control. Comparing the groups according to feeding programs, body fat content was in the order of sorghum > maize > wheat among the sole grain fed groups, and post-finisher plus sorghum > post-finisher plus maize > post-finisher plus wheat among the choice-fed groups.

Table 3.5 Carcass compositions of eight week-old birds (Dry matter basis)

	Post-finisher	**PF + Maize**	**PF + Wheat**	**PF + Sorghum**	**Maize**	**Wheat**	**Sorghum**
DM %	38.20 ± 0.717	37.98 ± 1.609	35.75 ± 0.272	39.55 ± 1.373	37.21 ± 0.333	38.72 ± 0.473	39.69 ± 0.473
Moisture %	61.80 ± 0.717	62.02 ± 1.609	64.25 ± 0.272	60.45 ± 1.373	62.79 ± 0.333	61.280 ± 0.473	60.31 ± 0.473
Ash %	6.55 ± 0.040	7.98 ± 0.793	6.99 ± 1.301	6.94 ± 0.303	7.58 ± 0.523	8.11 ± 1.327	6.47 ± 0.977
CP %	47.02 ± 0.911	47.05 ± 2.364	51.96 ± 1.117	45.83 ± 2.488	47.31 ± 1.031	46.53 ± 0.135	45.19 ± 1.342
Crude fat %	45.29 ± 1.644	45.12 ± 0.071	42.19 ± 1.761	46.26 ± 3.858	46.30 ± 0.882	44.47 ± 0.581	46.73 ± 2.688

3.1.4 Financial analysis

Financial analyses were carried out to determine the most economical feeding program. The feed costs were calculated based on the assumption that all other production costs would remain constant and only the feed cost would vary. The domestic average annual prices of the feedstuffs listed below were used.

Post-finisher = R2 076.44/tonne (Meadow Feed Mills Cape, 2000)

Maize = R 600.00/tonne (Bester Feed & Grain Exchange, 2001)

Wheat = R 550.00/tonne (Bester Feed & Grain Exchange, 2001)

Sorghum = R 580.00/tonne (Bester Feed & Grain Exchange, 2001)

The feed costs of feeding a single feedstuff (as shown in table 3.6) was calculated as follows:

Post-finisher = Price/kg x Quantity used (kg) eq. (2)

Choice feeding was calculated as:

Post-Finisher + Grain = $(P_pQ_p) + (P_gQ_g)$ eq. (3)

where P_p = price of post-finisher

Q_p = quantity of post-finisher consumed by the bird

P_g = price of grain

Q_g = quantity of grain consumed by the bird

Table 3.6 Feed cost (R/bird)

	Post-finisher	**PF + Maize**	**PF + Wheat**	**PF + Sorghum**	**Maize**	**Wheat**	**Sorghum**
Week 5-6	4.76	4.45	4.45	4.45	4.45	4.45	4.45
Week 7-8	4.09	2.31	3.64	3.42	0.84	0.72	0.86
Total	8.85	6.76	8.09	7.87	5.29	5.17	5.31
Cost/Live wt gain/ bird/4 weeks	4.96	3.51	4.45	4.30	4.37	3.81	4.76

There were no differences in feed costs among the choice fed groups during phase one of the trial. These groups however, appeared to have slightly lower feed costs when compared to the control. During phase two, the cost of feeding post-finisher plus maize was noticeably lower than the control and the other choice fed groups. There was little difference in feed cost between the sole sorghum and maize fed treatments but they both appeared to be slightly higher than the sole wheat fed group. The feed costs of sole grain fed groups appeared to be lower than that of the control group. Overall, the feed costs compared on the basis of a feeding program were in the order of post-finisher > choice feeding > sole grain.

Birds with a good FCR are cost efficient. This trait predetermines the efficiency of live weight gain per cost of feed. In this study, the total live weight gain over the duration of the experiment was used to calculate feed cost per live weight gain. Post-finisher plus maize fed birds appeared to have the lowest feed cost per kilograms of live weight gained when compared to all the treatments. The group fed on wheat only appeared to have the lowest feed cost per live weight gained among the sole grain fed treatments. This group also had the highest body weight gain among the sole grain fed groups. Thus its financial efficiency could be attributed to the high live weight gain.

3.2 DISCUSSION

Feed intake in poultry is governed by specific nutrients (Emmans, 1977; Hughes, 1984; Robinson, 1985; Rose and Kyriazakis, 1991; Forbes and Shariatmadari, 1994). Dietary energy concentration, among other nutrients, plays a major part because the level of dietary energy is inversely proportional to feed intake and FCR (Larbier and Leclercq, 1994). At constant protein/energy ratios, an increase in energy concentration tends to increase carcass fat content. This response is in part due to the presence of dietary fat invariably used to increase dietary energy concentration.

Research (Larbier and Leclercq, 1994) shows that adiposity could be improved by increasing dietary protein[3] because lipid gain declines symmetrically as protein gain increases. Larbier and Leclercq (1994) reported that on average, an increase of 10 g/kg dietary protein leads to a reduction of 7 – 14 g/kg body fat and a fall of 3 percent feed intake in broilers. However, the positive effect of modifying dietary protein in birds depends on the efficiency of protein conversion. Protein requirement for maximum protein gain is higher than that required for maximum live weight gain. It has also been reported that fatter birds tend to have lower efficiency of protein synthesis than leaner birds.

3.2.1 The effect of choice feeding broilers at the age of 5 to 6 weeks

The feedstuffs given to the birds in this study had different energy concentrations but there was no significant difference in feed intake among the treatments. The effect of dietary energy concentration on feed intake might not have been observed due to the varying energy content.

There were no significant differences among the treatments with regard to metabolisable energy intake (Table 3.2) and live weight gain (Figure 3.5) during the first two weeks of the trial. However, the post-finisher plus sorghum fed group appeared to have the highest body fat content as shown in Figure 3.6.

[3] The nature of protein has no influence on the results.

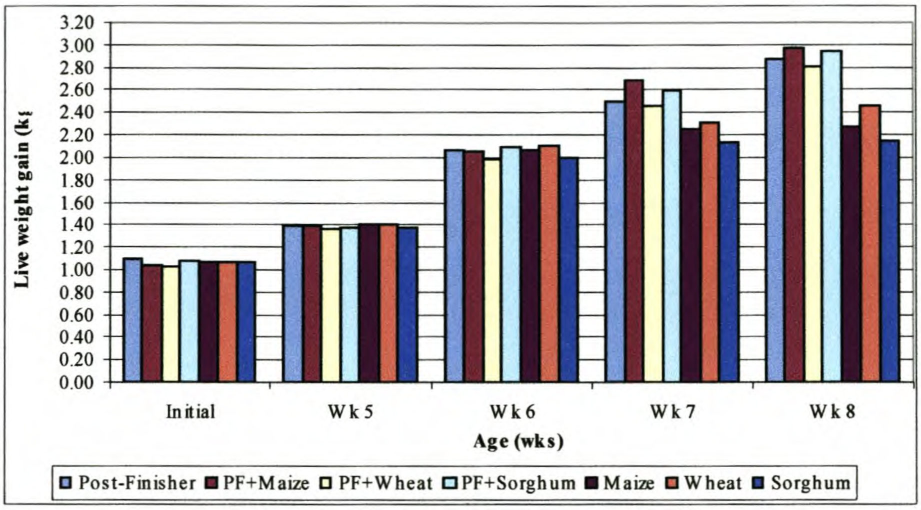

Figure 3.5 Live weight gain of broilers

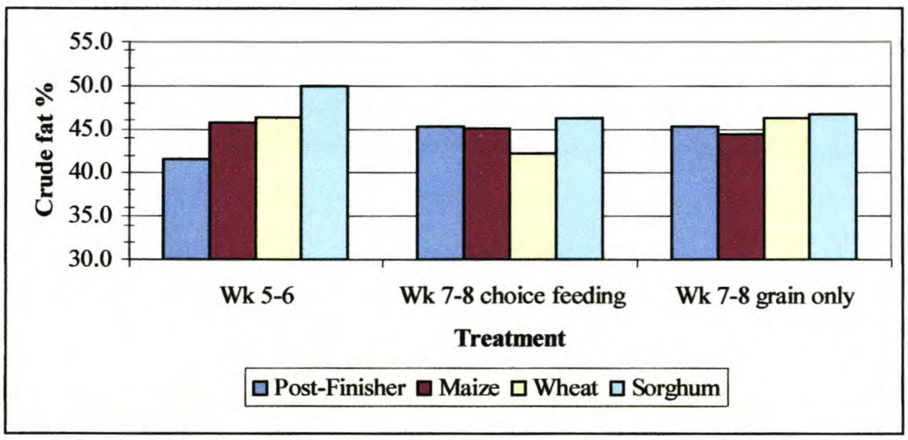

Figure 3.6 Crude fat content in carcass

Carcasses of birds choice-fed with wheat, appeared to contain slightly more body fat than the maize fed and the control groups. Similarly, Olver and Jonker (1997) found that the birds choice-fed with wheat, contained more body fat than the maize choice-fed group, but both higher than that of the control group at 6 weeks of age. Several factors contribute to adiposity as explained in the previous section. Since the energy intake of this group was the same as those of the other treatments, dietary fat intake might have contributed to the adiposity of the post-finisher plus wheat group.

The only dietary modification able to reduce fattening is an increase in crude protein. The post-finisher plus sorghum fed group had a relatively high protein intake (Table 3.2) but the efficiency with which this protein was used for protein synthesis was low, resulting in a low carcass protein content (Figure 3.7). Presumably, they used the protein for live weight gain. The control group had the lowest body fat content (Figure 3.6) and the highest crude protein (Figure 3.7) in the carcass. In general, choice-feeding broilers at this age had no notable effect on feed intake and live weight gain. These findings are in agreement with the findings of Oliver (1996) of very little difference in body mass between choice-fed birds and the control.

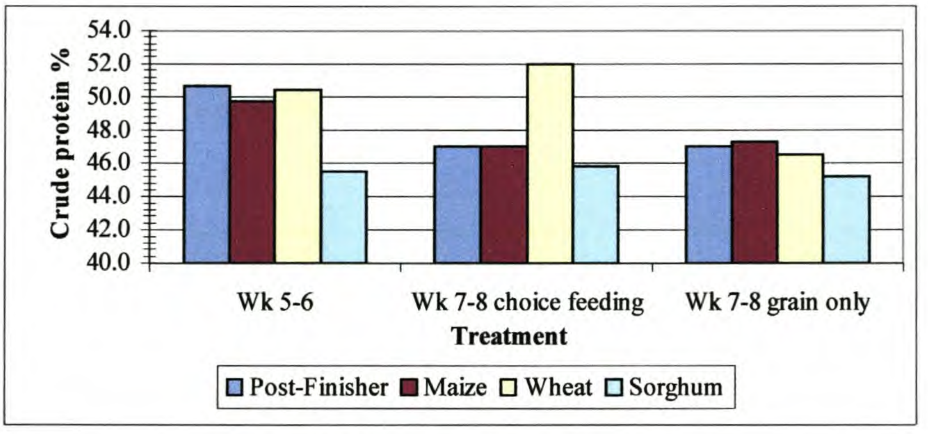

Figure 3.7 Crude protein content in carcass

3.2.2 The effect of choice feeding broilers at the age of 7 to 8 weeks

a) Post-finisher plus maize

Choice feeding with maize depressed feed intake by about 34% in comparison with the control group; this group had the lowest feed intake compared to the other choice-fed groups and the control group (Table 3.4). It however had the highest live weight gain and the highest feed efficiency of all the treatments. This group also had the lowest ME intake and a low dietary fat intakes, the fat intake was however slightly higher than that of the sorghum choice-fed group. Consequently, their carcasses had low body fat. Maize contained the lowest crude protein and as a result birds choice-fed on it had the lowest protein intake (Table 3.4). Nonetheless, these birds efficiently converted the dietary protein into body protein. It seems like these birds were efficiently converting both feed and the consumed nutrients to produce large carcasses of good quality in terms of protein and adiposity.

b) Post-finisher plus wheat

The birds that were choice-fed with wheat had the highest feed intake, which was not significantly different from that of the control group (Figure 3.4). They also had the highest ME_n, dietary fat, and protein intakes (Table 3.4). This group had the lowest live weight gain among the choice fed groups but slightly lower than the control, which implies that feed efficiency was poor. Covasa and Forbes (1995) also found significant differences in body weight between birds choice-fed with wheat and the control. In their study, though the difference was noted when the birds were 5 weeks old and no differences were noted at 6 and 8 weeks of age. These findings are in agreement with those of Olver and Jonker (1997) and other researchers (Anonymous, 1987), who reported that choice feeding wheat and a complete diet reduced FCR.

The carcasses of birds given post-finisher and wheat contained the lowest body fat (Figure 3.6) and the highest crude protein compared to the control (Figure 3.7). This shows that dietary protein was efficiently converted to body protein but contributed little to live weight gain. In addition, the high energy intake had little effect on adiposity.

c) Post-finisher plus sorghum

Sorghum choice-fed birds had a low feed intake, a lower energy intake and the lowest fat intake, but not significantly different from the control group (Table 3.4). Protein intake was also low. These birds had a high live weight gain, which was slightly higher but not significantly different from that of the control. Their carcasses however contained the lowest crude protein and the highest body fat. It seems like the birds efficiently converted feed and protein into live weight gain. Although energy intake was a bit low, dietary fat might have increased energy concentration and hence adiposity.

In general, statistical differences were noted between the treatments with regard to feed intake, nutrient intake, as well as their conversion efficiencies (Table 3.4). Choice feeding depressed feed intake of maize choice-fed group only while the other groups had feed intakes close to that of the control. Yet the live weight gain of the maize choice-fed group was remarkably higher than that of the control group whilst the gains of the other groups were slightly different from that of the control. Another effect was on adiposity, which was only evident in the sorghum choice-fed group.

Some researchers (Kleyn and Scharlach, 2000) argue that it is the digestive tract of the choice-fed birds that increases in size, not the carcass *per se*. In this study, only live weight gain was taken into consideration, not carcass yield. This was done because live weight gain was considered to be as important as slaughter weight in these feeding systems.

3.2.3 The effect of feeding sole grains to broilers at the age of 7 to 8 weeks

a) Maize

Maize fed birds had high feed, energy and fat intakes among the sole grain fed groups, but significantly lower than that of the control group. They had the lowest protein intake but their carcasses contained high crude protein, showing an efficient conversion of dietary protein into body protein (Table 3.4). This group nonetheless had a low live weight gain (Figure 3.5) and their carcasses contained a high amount of fat (Figure 3.6). Probably, the high energy intake contributed to the accumulation of body fat.

b) Wheat

Birds fed wheat only had the lowest feed and energy intakes in comparison with the control (Table 3.4). Although fat intake was low, protein intake was the highest among the sole grain fed groups, but lower than that of the control. The birds had the highest live weight gain. Their carcasses contained low amounts of crude protein and the lowest amounts of body fat. This implies a poor conversion of dietary protein into body protein but an efficient utilisation for live weight gain.

c) Sorghum

The sorghum fed birds had the highest feed and energy intakes, but lower than that of the control. They had the lowest fat intake and a relatively low protein intake (Table 3.4). These birds had the lowest live weight gain, which implies a depressed FCR. The crude protein content of the carcasses was high despite the low protein intake (Table 3.5). Although the group had the highest body fat content, among sole grain fed groups, it appeared to be lower in relation to the protein content in the same carcasses. These birds had poor feed efficiency and a high energy intake, which possibly contributed to the high body fat, but at the same time had a high protein efficiency to contain high body protein. According to Labier and Leclercq (1994), fat birds have poor protein efficiency. Although this group was not obese, it contained more body fat than those of the other groups on a similar feeding program.

In summary, sole grain feeding depressed feed intake by about 33%. It also depressed live weight gain by about 70% compared to the control. Nevertheless, the birds had already reached slaughter weight when put on this diet. Therefore they used the grains to maintain the same live weight rather than increase it. Carcass composition appeared to be closer, with some being better, to that of the control, implying that feeding sole grain to the birds kept them at maintenance.

3.2.4 Financial analysis

The post-finisher plus maize fed group had the lowest feed cost per live weight gain among all the treatments (Table 3.6). This could be due to the improvement in feed conversion induced by this treatment. Sole wheat-fed birds had the lowest feed cost per live weight gain among the sole grain-fed groups and the control group.

In summary, choice feeding birds from the age of 5 to 6 weeks did not have a notable effect in terms of both bird performance and cost efficiency. Choice feeding after they have reached market weight, from 7 to 8 weeks of age, proved to be beneficial. Birds fed post-finisher plus maize, had the highest live weight gain, contained acceptable amounts of body fat and had the lowest feed cost per live weight gain among choice fed birds. Among sole grain fed birds, wheat fed birds had the highest live weight gain, appeared to have a slightly lower amount of body fat, and had the lowest feed cost per live weight gain.

4. CONCLUSIONS AND RECOMMENDATIONS

From the results and discussion, it can be concluded that choice feeding with any of the grains or feeding the grains only to broilers that have reached slaughter weight, has no detrimental effect on the birds. The choice-fed birds performed better than the control group while the sole grain fed birds performed equally to the control group. Both the choice-fed and sole grain fed birds were economically efficient in comparison to the control group. Furthermore it can be concluded that:

i) Choice-fed birds had the highest live weight in the order of PF + maize > PF + sorghum > PF + wheat.

ii) Sole grain fed birds had lower live weights compared to the choice-fed and control groups in the order of wheat > maize > sorghum.

iii) Choice feeding with maize had the lowest feed cost per live weight gain compared to the other choice fed groups and the control group.

iv) Feeding wheat only had the lowest feed costs per live weight gain among the sole grain fed groups.

The results of this study could be recommended for small-scale farms that produce for live sales. The broiler breeds used nowadays have been bred to reach slaughter weight at the age of six weeks, which is about 1.8 kg. Some markets require larger birds, in which case a farmer is required to keep the birds on the farm longer than six weeks. Commercial complete diets, formulated for this purpose, are available. If farmers faced with such a situation have access to less expensive grains, it may safely be recommended that they choice feed with the grains, preferably maize, together with a complete diet to enhance live weight gain of the birds

Occasionally, farmers are required to keep birds on the farm longer after they have reached slaughter weight, due to lack of market. In such a case feeding sole grains, preferably wheat, instead of a complete diet to maintain the live weight of the birds, is recommendable.

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APPENDIX

This appendix contains raw data generated during the experiments.

Table A1 Live weight of birds

DURATION		Live weight, kg				
Wk 5-6	Wk 7-8	Initial wt	wk 6 wt	wt gain wk5-6	wk 8 wt	wt gain wk7-8
A	A	1.179	2.144	0.965	3.040	0.896
A	A	1.048	2.056	1.008	2.678	0.622
A	A	1.056	2.038	0.982	3.028	0.990
A	A	1.077	2.016	0.939	2.747	0.731
B	B	1.059	2.109	1.050	2.853	0.744
B	B	1.036	2.067	1.031	3.112	1.045
B	B	0.999	1.953	0.954	2.964	1.011
B	B	1.085	2.064	0.979	2.977	0.913
B	E	1.079	2.087	1.008	2.244	0.157
B	E	1.126	2.172	1.046	2.633	0.461
B	E	1.028	1.994	0.966	2.016	0.022
B	E	1.052	1.995	0.943	2.202	0.207
C	C	1.061	2.107	1.046	3.012	0.905
C	C	1.080	2.058	0.978	2.922	0.864
C	C	0.980	1.905	0.925	2.824	0.919
C	C	0.973	1.878	0.905	2.467	0.589
C	F	1.057	2.068	1.011	2.273	0.205
C	F	1.119	2.176	1.057	2.580	0.404
C	F	1.089	2.111	1.022	2.516	0.405
C	F	1.011	2.054	1.043	2.480	0.426
D	D	1.079	2.125	1.046	2.962	0.837
D	D	1.103	2.092	0.989	3.016	0.924
D	D	1.113	2.104	0.991	2.880	0.776
D	D	1.030	2.051	1.021	2.926	0.875
D	G	1.109	2.074	0.965	2.220	0.146
D	G	1.091	2.095	1.004	2.286	0.191
D	G	0.994	1.859	0.865	1.974	0.115
D	G	1.046	1.976	0.930	2.084	0.108

Table A2 Feed intake

DURATION		Feed intake, kg					
Wk 5-6	Wk 7-8	PF wk5-6	Grain wk5-6	PF+Grain wk6	PF wk7-8	Grain wk7-8	PF+Grain wk8
A	A	2.299	0.000	2.299	1.765	0.000	1.765
A	A	2.277	0.000	2.277	1.898	0.000	1.898
A	A	2.309	0.000	2.309	2.285	0.000	2.285
A	A	2.286	0.000	2.286	1.929	0.000	1.929
B	B	2.127	0.152	2.278	0.954	0.217	1.170
B	B	2.122	0.179	2.301	0.988	0.183	1.172
B	B	2.035	0.175	2.210	0.967	0.332	1.299
B	B	2.061	0.238	2.299	1.243	0.288	1.531
B	E	2.126	0.178	2.304	0.000	1.668	1.668
B	E	2.145	0.197	2.342	0.000	1.137	1.137
B	E	2.030	0.199	2.229	0.000	1.289	1.289
B	E	2.069	0.145	2.214	0.000	1.483	1.483
C	C	2.159	0.199	2.358	2.037	0.460	2.497
C	C	2.092	0.179	2.271	1.496	0.197	1.693
C	C	2.075	0.199	2.274	1.892	0.257	2.149
C	C	1.952	0.148	2.100	1.309	0.164	1.473
C	F	2.120	0.199	2.319	0.000	1.283	1.283
C	F	2.161	0.195	2.356	0.000	1.147	1.147
C	F	2.117	0.240	2.357	0.000	1.465	1.465
C	F	2.069	0.177	2.246	0.000	1.332	1.332
D	D	2.171	0.196	2.367	1.327	0.221	1.547
D	D	2.119	0.198	2.317	1.662	0.397	2.060
D	D	2.138	0.179	2.317	1.398	0.278	1.676
D	D	2.093	0.200	2.293	1.848	0.339	2.187
D	G	2.102	0.177	2.279	0.000	1.664	1.664
D	G	2.135	0.159	2.294	0.000	1.423	1.423
D	G	1.944	0.198	2.142	0.000	1.598	1.598
D	G	2.039	0.179	2.218	0.000	1.221	1.221

Table A3 Nutrient intake

DURATION		Nutrient intake, g/kg feed					
Wk 5-6	Wk 7-8	CP wk5-6	CP wk7-8	ME wk5-6 (MJ/kg)	ME wk7-8 (MJ/kg)	Fat wk5-6	Fat wk7-8
A	A	159.352	170.000	0.306	0.235	53.430	57.000
A	A	159.249	170.000	0.303	0.252	53.395	57.000
A	A	159.398	170.000	0.307	0.304	53.445	57.000
A	A	159.291	170.000	0.304	0.257	53.409	57.000
B	B	163.694	152.433	0.304	0.157	55.629	53.181
B	B	162.621	155.160	0.307	0.157	55.396	53.774
B	B	162.481	145.798	0.295	0.175	55.365	51.738
B	B	160.179	152.176	0.308	0.206	54.865	53.125
B	E	162.665	75.200	0.308	0.234	55.405	36.390
B	E	162.022	75.200	0.313	0.159	55.266	36.390
B	E	161.533	75.200	0.298	0.181	55.159	36.390
B	E	163.799	75.200	0.295	0.208	55.652	36.390
C	C	166.435	162.223	0.313	0.331	54.982	52.597
C	C	166.672	165.081	0.302	0.225	55.116	54.215
C	C	166.305	164.952	0.302	0.285	54.908	54.142
C	C	167.020	165.301	0.279	0.196	55.313	54.340
C	F	166.382	127.800	0.308	0.168	54.952	33.110
C	F	166.501	127.800	0.313	0.150	55.019	33.110
C	F	165.711	127.800	0.313	0.191	54.572	33.110
C	F	166.676	127.800	0.298	0.174	55.118	33.110
D	D	164.049	159.742	0.315	0.206	54.782	53.176
D	D	163.864	156.129	0.308	0.274	54.713	51.830
D	D	164.442	158.081	0.308	0.223	54.928	52.557
D	D	163.743	158.861	0.305	0.291	54.668	52.848
D	G	164.419	98.100	0.303	0.224	54.920	30.200
D	G	165.019	98.100	0.305	0.191	55.144	30.200
D	G	163.357	98.100	0.285	0.215	54.524	30.200
D	G	164.200	98.100	0.295	0.164	54.838	30.200

Table A4 Feed and nutrient conversion ratios

DURATION		Conversion ratios (kg live weight/kg feed)					
Wk 5-6	Wk 7-8	FCR wk5-6	FCR wk7-8	Protein CR wk5-6	Protein CR wk7-8	ME CR wk5-6	ME CR wk7-8
A	A	2.382	1.970	0.380	0.335	0.306	0.235
A	A	2.259	3.051	0.360	0.519	0.303	0.252
A	A	2.351	2.309	0.375	0.393	0.307	0.304
A	A	2.435	2.640	0.388	0.449	0.304	0.257
B	B	2.170	1.572	0.355	0.240	0.304	0.157
B	B	2.232	1.121	0.363	0.174	0.307	0.157
B	B	2.317	1.284	0.376	0.187	0.295	0.175
B	B	2.349	1.678	0.376	0.255	0.308	0.206
B	E	2.286	10.624	0.372	0.799	0.308	0.234
B	E	2.239	2.464	0.363	0.185	0.313	0.159
B	E	2.308	58.600	0.373	4.407	0.298	0.181
B	E	2.348	7.157	0.385	0.538	0.295	0.208
C	C	2.254	2.759	0.375	0.448	0.313	0.331
C	C	2.322	1.960	0.387	0.324	0.302	0.225
C	C	2.458	2.339	0.409	0.386	0.302	0.285
C	C	2.321	2.502	0.388	0.414	0.279	0.196
C	F	2.294	6.247	0.382	0.798	0.308	0.168
C	F	2.229	2.839	0.371	0.363	0.313	0.150
C	F	2.306	3.618	0.382	0.462	0.313	0.191
C	F	2.153	3.127	0.359	0.400	0.298	0.174
D	D	2.263	1.848	0.371	0.295	0.315	0.206
D	D	2.342	2.230	0.384	0.348	0.308	0.274
D	D	2.338	2.160	0.384	0.341	0.308	0.223
D	D	2.245	2.499	0.368	0.397	0.305	0.291
D	G	2.362	11.395	0.388	1.118	0.303	0.224
D	G	2.285	7.452	0.377	0.731	0.305	0.191
D	G	2.476	13.895	0.405	1.363	0.285	0.215
D	G	2.385	11.257	0.392	1.104	0.295	0.164