Choice Feeding as a Method of Meeting the Changing Protein Requirements of Broilers During their Growing Period

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DECLARATION

We hereby declare that the research reported in this thesis does not contain material which has been accepted for the award of any other degree or diploma in another University and, to the best of our knowledge, does not contain material previously published or written by another person, except where due reference is made in the text.

M..S. Abdella

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Chapter 1

Literature Review

1.1 General introduction

Broiler production is an important animal production enterprise with potential to make high returns. Increasing feed efficiency and early body weight gain has always been a top priority in the broiler industry. The general objective of broiler nutrition is to maximise production performance and profitability. Nutrition is of major importance in raising chicken, and feed is a major input in poultry production systems, accounting for over 60% of total production costs in commercial poultry sector Renkema (1992). The cost of feed is therefore often a constraint especially in developing countries. For instance, Onyenokwe (1994) observed that high cost of feed ingredients in many African countries has caused many poultry farmers to abandon the industry. The continued rise in feed prices is due to competition for some of the ingredients with human e.g. sorghum, wheat and maize. Broiler farmers are therefore forced to use combinations of feed ingredients of low cost to obtain savings and avoid any further loss of profits. It is therefore important to give special attention to feed and feeding since the rate of feed consumption increases rapidly with advancing age of the birds and good nutrition is reflected in the bird's performance and its products.

The profitability of a broiler enterprise depends on the efficient conversion of feed to meat. Broilers have the ability to convert the feeds into meat with a high efficiency. For instance Morris and Njuru (1990) reported that broilers have much higher daily rates of protein deposition than layer chicken strains. This implies that fast-growing strains would require greater daily protein intakes than slow-growing ones. In the past, the major criteria for assessing the performance of broilers has been growth rate and feed conversion ratio (FCR). Diet specifications and feeding programmes have been aimed at maximising these two parameters whereby overall flock performance is calculated based on the total weight of chicken produced from total feed deliveries. With the new developments in understanding of nutritional factors affecting broiler growth and carcass composition, it is now possible to apply sophisticated and yet efficient approaches to feeding broilers.

1.2 Limitations in feeding practices

Most commercial poultry farmers offer their birds only one feed at a time, the composition of which is changed as the broilers grow. As the broilers are forced to consume the given feed, they have no opportunity of balancing nutrient intake thereby meeting their nutrient requirements, which differ considerably both as the birds grow, and within a mixed flock. Broilers, like all other animals, require nutrients for two purposes: to maintain the essential functions of their bodies and to allow for growth and production. They are mostly selected for growth rate and food conversion ratio and have ability to convert low quality ingredients into high value products. The daily amino acid requirements of growing birds increase throughout the growing period, although when these are converted to dietary concentrations, the requirements decrease with age. David *et al* (1994) reported that the amino acid requirements couldn't apply to all birds under all dietary, sex, and body compositional circumstances. But the ideal ratio of indispensable amino acids to lysine should remain largely unaffected by any variables. Thus within each feeding phase broilers would go through a cycle in which the protein content is likely to be inadequate initially, and then more than adequate.

Theoretically, it can be argued that by allowing the birds access at the same time to two feeds differing in protein content, the under-and over-supply of dietary protein would be considerably reduced, leading to a more efficient system of supplying them with the ration they need. The conventional method of meeting these changing requirements over time is to use a phase feeding system where a series of feeds is offered to the animals according to their stage of development (but usually based on the age of the birds). By reducing the content of protein in each of the feeds in the programme whilst keeping energy and all other essential nutrients the same, the changing requirements of the growing birds are catered for. However, periods of under- and over-supply of protein are guaranteed with such a feeding method, but these periods are of shorter duration than if only one feed were offered throughout the growing period. An alternative to this phase-feeding technique is where two feeds, one high and the other low in protein are offered simultaneously, and the broilers have the option of choosing a blend of these two feeds, which has the potential to match more closely the changing amino acid requirements of the bird. The following review gives an insight into this method of feeding i.e. the choice feeding system.

1.3 Choice feeding concept

The ability of chickens to select a balanced diet, if offered a choice of various feed ingredients, had been demonstrated a long time ago and confirmed by Emmans (1977) and Summers and Leeson (1978). There is considerable evidence that broilers are able to meet their requirements for energy and protein independently by selection from two or more feeds Hruby *et al.*, (1995). Feed or nutrient requirement has been observed in birds Michie, (1977) to vary with strain, age, sex, and environmental factors. Emmans (1991) has illustrated food composition as occupying a dietary space with three components, namely, protein, energy and minerals, the relative proportions of each defining the composition of the food. Depending on the combination chosen the blend could be seen as being adequate or inadequate. By selecting feed randomly, or with the choice being made on the basis of preferences for colour, taste or other non-nutritional characteristics, it is unlikely that the bird would make the best choice from a nutritional point of view. However, evidence to indicate that the birds are selecting foods with a nutritional purpose is strengthened if their requirements change with time and this change is reflected in appropriate adjustments to the proportions of different foods chosen Kyriazakis and Emmans (1991). Picard *et al.*, (1997) found that chicken adapted to the dietary choice as they reduced their protein intake proportionally to their age (and not to their actual live weight). This means the broilers did not balance their choice to meet their protein requirements for optimal growth.

The basic principle of choice feeding is that a population of birds is made up of individuals with different physiological and nutritional requirements, and that each animal may choose a blend between two feeds that, in some proportion, meet its unique requirements for protein plus energy and possibly other nutrients Belyavin (1993). Choice feeding therefore involves availing of two or more feed ingredients or mixed feeds to broilers and allowing them to choose a feed blend that meets their requirement for maximum growth. Birds by nature are curios, which is why they first sample feedstuffs to find out if they are nutritious or palatable before continuing to feed on them, so the role of learning and experience plays an important part in choice feeding. However, it is easier to develop specific appetites for some nutrients than for others (Hughes, 1984). Birds are able to discriminate between feed sources and when offered a choice between feeds can select a mixture of the major nutrients for their individual needs. Picard *et al.* (1993) reported that discrimination among diets differing in essential amino acid contents was more sensitive in fast growing chickens than in chickens selected for egg production. Leeson and Summers (1978) showed that 24 weeks old birds receiving the split-diets *ad libitum* showed only small reduction in food intake and egg production and they gained more weight than restricted feeding.

The free choice technique has been used to test the ability of the broiler chicken to make the right choice (Gous and Swatson, 2000). The fact, that as broilers grow their nutrient requirements change, they require a higher concentration of dietary protein at a young age to meet their needs for growth than they do later, mainly because of the low feed intake at early stage. As they grow, the concentration of protein required is reduced, and the broilers change the proportions selected to match their changing requirements (Shariatmadari and Forbes 1993). Similarly, work by Bradford (1988) using choice-feeding, phase-feeding and single-feeding, showed that pigs chose to consume feed of a lower protein concentration as they get older.

1.3.1 Some factors to consider in broiler choice feeding systems

Temperature

House temperature is one of the many important factors influencing feed conversion in the broilers environment. Generally, broilers consume less feed, and convert this feed less efficiently at high environmental temperatures (Bonnet *et al.*, 1997). Likewise, broilers maintenance needs are greatly influenced by the environmental temperature. Under ideal conditions of around 20-25°C, the bird uses a minimum of feed to maintain body temperature; otherwise, feed intake is inversely related to environmental temperature. Cheng *et al,* (1997) illustrated that broilers reared in hot ambient temperatures of 29°C during 3 to 6 weeks growing period have difficulty in maintaining their body temperature. Cumming *et al.* (1987) applied choice feeding as a means of controlling heat stress. The cited workers offered energy and protein sources separately and found that young broilers have the ability to adjust their nutrient intake according to varying ambient temperatures. Broilers reared under high environmental temperature chose a diet lower in total protein starting between 6 and 7 week of age (Cowan and Michie, 1978; Hruby *et al.*, 1995). Blake (1984) reported that the laying hens reduced egg production significantly under high temperature. This response reflects the inability of the hens to meet daily nutrients requirement by selecting from three different feeds. However, Sinurat and Balnave (1986) found that commercial broiler chicks from 0 to 21 day of age given complete diets grew faster with greater efficiency of food utilisation than the group given a free-choice selection of the cereal and protein components at a high ambient temperature (25-35°C).

Feed quality

Variation in quality of a particular basal feed needs to be taken into account in choice feeding. For instance, some ten years ago, choice feeding of broilers became popular in some parts of Europe, when it was shown that acceptable growth rates could be achieved when birds were allowed simultaneous access to a balanced feed and whole grain cereals such as wheat Leeson and Caston, (1993). The cited workers further remarked that cereals such as wheat comprise a large component of poultry feeds, but wheat is not of uniformly high nutritional value when fed to non-ruminants, particularly poultry. The gizzard has the capacity to break down the grains quickly; so whole grains could be fed without any adverse effect on body weight or feed consumption. Salah *et al.* (1996) showed that different wheat varieties had similar effects on growth rates, food conversion ratios and performance, and that feeds diluted with wheat may be profitable because of the limited effect on bird performance but with food intake reduced significantly. This is attributable to reduction in feed intake as the content of feed grains is increased, so there is an indication of a reduced overall feed cost when broilers are given the opportunity to select cereal free choice. It is possible that the reason for the improvement in performance from consumption of whole wheat was due to changes in the size of the gizzard, which in turn improved litter quality as well.

Some trials conducted by Leeson and Caston (1993) to investigate the performance of broilers given a choice of starter and finisher feeds to market age, compared with those given the starter, grower and finisher feeds in sequence, showed that diet self-selection had no effect on body weight at 49 days, and that all birds consumed similar proportion of total food. Their results showed that the birds tended to prefer the high-energy feed and there was also good evidence that the overall feed cost decreased when the broilers were offered cereals as a choice. Shariatmadari and Forbes (1993) showed that broilers had the ability to select an adequate amount of protein to attain their potential when a choice between high and low protein diets was offered.

Mode of feed presentation

Summers (1978) observed poor results in an experiment in which the position of the bins containing high- protein or low-protein feeds were changed every three days. The troughs were swapped to try and eliminate any positional biases, but did not take into account the possibility that positional bias may be stronger than any nutritional characteristics, and this in turn resulted in reduced biological performance by the birds. It has been shown (Forbes and Shariatmadari, 1994, Munt *et al.*, 1995) that although birds appear to have a great degree of nutritional wisdom as far as protein is concerned, they need to be able to differentiate between foods with different nutrient profiles by sensory and other means, e.g. colour, texture, position of trough, etc. The design and placement of feed troughs may have an impact on choice feeding trials. Bradford (1988) demonstrated this by placing two feeders at opposite sides of the pen of pigs and obtained poor results compared to when the feeders were placed side by side. Experiments with pigs (Hughes, 1984, Bradford, 1988) showed that trough placement had an effect on the choice made by the pigs, as did the palatability of the diets offered and previous experience of the animals. When little difference exists in the palatability or chemical content of the two feeds on offer, pigs learn to differentiate between them by trough placement. If the trough position is changed randomly, this cue is lost and the pigs cannot differentiate successfully between the two feeds. Forbes (1995) found that when an initial meal of low protein feed was followed by choice of high and low protein feeds; birds ate greater proportion of the high protein feed when it was placed on the opposite side of the cage from that in which initial meal was given.

With regard to choice feeding system, Rose and Kyriazakis (1991) stressed that all birds should be allowed free access to all feeds at all times to ensure the birds are actually making a nutritionally sound choice and not merely responding to some other stimulus.

Presence of anti-nutritive compounds

Some limits to feed selection in animals result from the presence of toxins in feeds, giving rise to an aversive taste and the consequent refusal of the birds to eat (Hughes, 1984). This can work in favour of choice feeding where the presence of toxins is being investigated. In trial using pigs, Bradford and Gous (1991) observed that when one of the food contain anti-nutritive or unpalatable components as a choice, they actively selected against this.

Physical form of feed

Rose *et al.* (1980) found that shape or form of the feed can have a major influence on feed choice, though there was no significant effect on total diet intakes or weight gains. The broilers tended to consume greater amount of crushed wheat when all feeds were offered as free choice. Several studies on the adaptation of chicks during the early post hatch period indicate that initial feed preferences are based on colour, form, or size of particles, and tactile cues, one-day-old chicks prefer to peck at round rather than angular objects; also they prefer to peck at small (0.3cm) sized feed. (Goodwin and Hess, 1969; Turro-Vincent *et al.*, 1994). If the composition of the feed changes due to availability of grains, the hens may not change easily to eating seeds of a different shape or colour (Goodwin and Hess, 1969). The form feed influence the amount of protein and energy intake (Siegel *et al.,* 1997), whereby pelleted diet has higher intake than mashed diet. Chickens prefer to eat particles that are smaller than their mouth cavity (Penz, 2002).

Previous experience and training

Forbes and Shariatmadari (1994), Forbes and Covasa (1995) reported that the previous learning for both growing and laying birds is very important before proficiency in the selection of feedstuffs is accomplished.

Day-old chicks offered side by side access to ground corn and a protein concentrate clearly showed a marked preference for corn during the first 4 h and this was attributed to lack of previous experience with the two feeds offered (Cumming, 1987). Thus the competence of poultry to learn to choose between two feeds usually improves if there is a period of prior exposure to the diets, hence allowing them to learn the nutritional and metabolic characteristics of each feed. Conversely, Covasa and Forbes (1994) found that the best results were achieved when the birds were introduced to the choice feeding without prior experience. However, when chicks in the post-hatching period have been offered only one food for several hours, a learning period would help them to differentiate between the foods (Forbes and Shariatmadari, 1994). Even training chickens with alternate feeds has its limitations as birds may condition themselves to starve until the normal feed is provided again (Rose and Fielden, 1994). Similar results have been obtained when choice feeding used with other animals, for instance, in a studies conducted on pigs, it was found that the learning period could be shortened if the pigs were only allowed access to one feed at a time, on alternating days before the choice feeding trial began (Gous *et al.*, 1989).

The bird's age

The age at which birds are exposed to choice feeding appears to have effect on their ability to choose an appropriate blend of feeds. Covasa and Forbes (1995) conducted experiments to determine whether age of training is necessary before introducing birds to cereal grains or conventional foods. They found that the earlier the birds were choice fed, the better the birds tended to perform later on. Adret-Hausberger and Cumming (1987) remarked that in young broilers living in groups, individuals learn from each other and balance energy and protein intake to their individual needs.

1.4 Discussion

Broiler production is a business, and like any other business the ultimate objective is to maximize profit generated from sales. In the case of broiler production, the income generated is dependent on the growth and quality of the broilers produced. These two important factors on which the sustainability of the enterprise are dependent on the management strategies imposed on them, by the producer of which feeding is crucial.

When broilers are given a single feed, their nutrient intake will depend on the composition and digestibility of the food. This often prevents the broilers from growing to their potential and thereby reduces the revenue obtained. Furthermore, it appears that when chickens are offered a single feed they tend to consume more of some nutrients as a means of meeting the requirement for the limiting nutrient in the feed. This tends to result in chickens depositing excessive fat, (which is less desirable) while reducing breast meat yield.

The goal of choice feeding experiments is, therefore, to establish the combination of components that maximise biological performance with the combination chosen by birds given *ad libitum* access to these components from the available resources. Thus, a choice-feeding system may enable broilers to achieve their maximum performance whilst minimizing excessive intakes of the non-limiting nutrients in the feeds on offer. This system also improves the chances of providing the broilers with all essential nutrients, as these may be in one or the other of the feeds on offer.

If broilers have the ability to meet their requirements from a chosen blend of the feeds on offer, they may well maximise their biological efficiency, but not maximise profitability for the farmer. This is especially true if one of the feeds on offer (the less-expensive of the two) is lacking in a nutrient that is present in the more expensive feed. The broilers may choose the more expensive feed simply to obtain sufficient of this nutrient, even though this may result in the over-consumption of the other nutrients in that feed. But here at least the broiler has the option of finding a different source of the limiting nutrient in this case, which would not be the case if only one feed were offered.

The use of two well-balanced protein sources is one option for a successful choice feeding system in practice, although this is not generally used. More common is a choice of a cereal and a protein balancer, but where broilers are expected to make a considered choice in the latter case, the result of increasing the cereal content of the blend results in less calcium and phosphorus, an increasingly unbalanced amino acid mixture, and a considerable increase in the energy: protein ratio in the blend. This may well be the reason for the poor results obtained when such feeding practices are used. It is imperative, for choice feeding to be successful, that the birds can balance all nutrients from a blend of the two or more feeds on offer; otherwise the birds face the same dilemmas as those being given only one feed at a time.

It is therefore clear from the reviewed literature that choice feeding can be used to enhance the productivity of the broiler industry, but there are several mitigating factors to consider.

The current study was therefore undertaken to use choice feeding strategy in broiler production with the following objectives: the broad objective of the present work focussed on young broilers from one to 21day-old to investigate the ability of broiler chickens to improve efficiency of utilisation of nutrients when given a choice of two feeds rather than one at a time. The specific objectives were to (i) determine whether and how broiler chickens can attain their genetic potential when supplied with a choice of two feeds, when one is high in protein and the other is low and (ii) compare the performance of free-choice-fed broilers with those fed a single feed. These can lead to further research directed at investigating the ability of broilers to differentiate between more than one feed in a choice feeding system.

Chapter 2

Choice feeding as a means of meeting the changing amino acid requirements of broilers between day old and 21d of age

2.1 Introduction

It is well known that as broilers grow their nutrient requirements, as a proportion in the feed, decline. That is, very young broilers growing at an extremely fast rate relative to their body size require the highest nutrient contents, i.e. when their relative growth rate is higher than at any other stage of growth require. This relative growth rate declines throughout the life of the broiler, reaching zero at maturity. The amino acid contents of the proteins deposited in the bird remain relatively constant for the same proteins (Hughes, 1984), but these differ considerably between proteins such as body and feather protein. Therefore, the rates of growth and the compositions of the different proteins need to be known in order to calculate the amino acid requirements of the broiler at different stages of growth. In modern broiler diets, more emphasis should be placed on the amino acid content and balance than the protein level in the diet, since weight gain is dependent on the amino acid intake rather than protein consumption (Rose and Kyriazakis, 1991).

The amino acid requirements of male and female broilers differ, with male broilers having higher requirements than females (Peisker, 1999). This makes it essential that feeds be formulated according to the requirement of each sex. However, although it is known that their nutrient requirements vary, they are normally fed a single feed that may either under- or over-supply the amino acids required by one of the sexes (Penz, 2002). Hence, it is essential that such broilers are either sexed and then given separate feeds, or given an opportunity to select according to their requirements, and choice feeding may play a crucial role in this regard, to make the broiler production enterprise more efficient and profitable.

The concentration of amino acid in the diet producing the maximum growth response is often regarded as being the requirement for that amino acid. However, Sibbald and Wolynetz (1986) showed that the lysine requirement for maximum protein accretion was significantly higher than that required for maximum weight gain of broilers. Fisher *et al.* (1973) reported that there was a benefit in seeing the requirements of animals as variable, dependent on the marginal cost of the amino acid and the marginal returns of the product, rather than static. In this way, the 'requirements' may be defined according to the objective of the enterprise, e.g. maximizing breast meat yield, minimizing fat content, maximizing profit, etc.

Choice–feeding systems in broilers allowing access to high and low protein foods have been proposed by Emmans (1977) to allow broilers to meet their own energy and protein requirements. By selecting their nutrient needs from a range of foodstuffs, chickens can adjust intakes according to their requirement for growth, production, and maintenance (Hughes, 1984). In most choice-feeding work, two formulated feeds are offered to birds and the birds balance intakes of the diets to satisfy their changing needs as they grow. However, the provision of a third feed will add an extra dimension to the ability of the broiler chicken to make the right choice. Requirements for protein, energy, minerals and vitamins are different between individual broilers within one batch so, when given a choice, all the individuals are able to select the correct balance by eating different proportions of the feeds on offer (Belyavin, 1993; Forbes, 1995).

Researchers have shown that choice-fed broilers often perform better than broilers fed a single, 'complete' feed, when the nutritional difference between two diets given as a choice is large and when they are given a learning period (Rose & Kyriazakis, 1991; Belyavin, 1993). They have this inherent ability as, under natural conditions, animals encounter many foodstuffs, some of which are nutritionally balanced and others that are unbalanced, and to ingest an adequate diet they require mechanisms that allow them to select appropriate amounts of each food (Hughes, 1979).

The phase–feeding system used in feeding broilers involves the serial feeding of a number of different feeds, closely matching the requirements of the chickens, at different stages of the growing period. It is expected that phase-feeding and choice feeding could yield similar results, but choice feeding is simpler to implement, and takes into account the differences in amino acid requirements both between sexes and at different stages of growth.

The objective of this study was to determine whether broiler chickens will attain their genetic potential when supplied with a choice of two feeds varying in dietary protein content, and also whether the performance of the choice-fed broilers will be higher than those fed a single feed.

2.2 Materials and Methods

2.2.1 Feeds and feeding treatment

Two basal feeds, one high (HP) (Feed A) and the other low (LP) (Feed B) in protein, were formulated (Table 2.1) using Winfeed to contain the same amounts of metabolisable energy (ME) and major minerals, using a well balanced amino acid mixture that remained the same in both feeds. These two basal feeds were blended (0.67 HP and 0.33 LP; 0.33HP and 0.67 LP) to produce two additional feeds (Feeds C and D respectively) with intermediate protein contents (Table 2.2). A fifth feed (Feed E) was made by adding synthetic lysine (L–lysine HCL at 3g/kg) to LP. This feed was offered as a choice with the unsupplemented low protein feed (Feed B) to ascertain whether the birds would choose a feed with a higher lysine content, i.e. whether lysine was limiting in LP. All combinations of feeds A to D were offered as choices, as well as the choice between D and E, resulting in six choice treatments. A summary of all treatments used in the trial is given in Table 2.2. The two basal feeds were sampled after mixing, and these samples were analysed for apparent metabolisable energy (AME) and digestible amino acid content. The chemical composition of the two basal feeds is shown in (Table 2.1)

2.2.2 Birds and housing

The experiment was conducted in the brooder facility at Ukulinga research farm. Four hundred and eighty day-old sexed Ross broiler chicks were purchased from National Chicks South Africa PTY Ltd. Chickens were housed in 48 cages, with 10 chickens randomly selected and placed in each cage; the sexes were reared, separately. The chickens were kept in these pens until 21d of age, after which the trial was terminated. Each cage measured 80 x 50 cm and was supplied with two feed troughs with a feed saver grid. Food bins were filled with test food at the beginning of the experiment and weighed. The test food was transferred from the bins to the food troughs when necessary.

Table 2.1 *Composition (g/kg) of the two basal feeds used in the trial. Amino acids are reported as digestible*

Ingredient	HP		LP	
Maize	423.7		584.1	
Full fat Soya	1.8		-	
Wheat bran	-		111.2	
Soya oilcake	377.2		191.2	
Fish meal 65	100.0		-	
L-lysine	1.4		-	
DL methionine	1.8		-	
Threonine	0.7		-	
Vit + mineral premix	1.5		1.5	
Limestone	9.9		18.8	
MCP	8.3		14.6	
Sodium bicarbonate	5.1		4.8	
Oil-sunflower	68.6		71.2	
Salt	2.6		2.4	
Nutrient	Formulated	Analysed	Formulated	Analysed
Protein	279.1	282.4	155.5	167.6
AMEn (MJ/kg)	13.0	14.0	13.0	13.5
TMEn (MJ/kg)	-	14.1	-	14.0
Dry matter (%)	89.5	88.6	88.7	88.4
Digestible amino acids				
Threonine	8.9	9.1	7.8	5.8
Valine	14.6	9.7	8.5	10.0
Methionine	4.3	5.0	4.1	2.0
Leucine	11.5	8.6	7.4	7.2
Isoleucine	20.8	15.2	1.3	14.3
Tyrosine	5.6	7.9	6.8	3.3
Phenylalanine	10.5	7.9	6.8	7.2
Histamine	5.8	5.3	4.3	4.8
Lysine	14.6	15.1	12.4	8.8
Arginine	16.0	14.6	12.4	11.0

At the end of each week, food remaining in each trough was returned to the bins, which were then weighed to determine the amount of food consumed each week. Each cage had two nipple drinkers, and both water and food were supplied *ad libitum*. Heat was supplied by means of a gas heater blower. The temperature was set at 29.5^{0}C throughout the brooder room, and was reduced by 1^{0}C every 3d until 23^{0}C was reached at 21d of age. Mortality was recorded as it occurred.

Table 2.2 *Feeding treatments applied during the trial.*

Treatment	Feeds	Protein content (g/kg)
1	A	282
2	B	244
3	C	205
4	D	168
5	E	3
6	A vs. B	
7	A vs. C	
8	A vs. D	
9	B vs. C	
10	B vs. D	
11	C vs. D	
12	D vs. E	

2.2.3 Measurements

The chicks were weighed in groups of ten to obtain the mean body weight for each cage at day old and at 7, 14 and 21d. Feed consumption was recorded at the end of each week. The response to the dietary treatments was assessed in terms of body weight gain, food intake and food conversion efficiency (FCE).

2.2.4 Statistical analysis.

The experiment was a randomised block design in which the experimental structure resulted in 12 treatments that were replicated twice for each sex. Data recorded were analysed to obtain treatment means and standard errors of the mean using an analysis of variance (Minitab, 1994).

2.3 Results

Body weight gain (g/bird d) feed intake (g/bird d), feed conversion efficiencies (g gain/kg feed consumed) were determined, and these are shown in Table 2.3.

Table 2.3 *Mean body weight gain, food intake and food conversion efficiency (FCE) (g gain/kg feed consumption) of male and female broilers on 12 feed treatments from day old to 21 d*

		Body weight gain (g/d)			Food intake (g/d)			FCE (g/kg)		
TRT		M	F	Mean	M	F	Mean	M	F	Mean
1	A	27.5	27.4	27.5	36.3	37.0	36.7	758	741	749
2	B	27.2	26.4	26.8	36.0	35.0	35.5	756	754	755
3	C	26.9	25.5	26.2	38.0	36.4	37.2	708	701	704
4	D	14.2	16.9	15.6	26.3	32.0	29.2	540	528	534
5	E	28.6	27.0	27.8	38.2	38.1	38.2	749	709	729
6	A vs. B	29.9	27.2	28.6	39.3	37.4	38.4	761	727	744
7	A vs. C	25.0	25.5	25.3	35.2	37.0	36.1	710	689	700
8	A vs. D	26.4	27.3	26.8	36.0	36.5	36.3	733	747	740
9	B vs. C	26.6	26.1	26.4	39.0	38.1	38.6	682	685	684
10	B vs. D	24.0	23.7	23.9	36.3	36.0	36.2	661	658	660
11	C vs. D	13.9	16.2	15.1	26.1	29.0	27.5	533	559	546
12	D vs. E	16.3	17.2	16.8	30.2	28.4	29.3	540	606	573
SEM			1.36			2.69			16.9	
LSD			5.76			11.22			139.5	

2.3.1 Body weight gain

There were no significant differences in body weight gain between sexes. Body weight gain increased significantly as protein intake increased from 5.4 to 10.2g/d. Body weight gain was significantly lower ($P<0.05$) when chicks were fed the low protein feed (T4), and when given a choice between C and D (T11). No significant difference was noted when offering broilers a single feed and a choice except where Feed D was one of the feeds on offer: gains improved from 15.6g/d on D to 26.8 and 23.9g/d respectively when feeds A and B were offered as a choice with Feed D. Birds gained more weight when they were given E (D plus Lysine HCl) than on D.

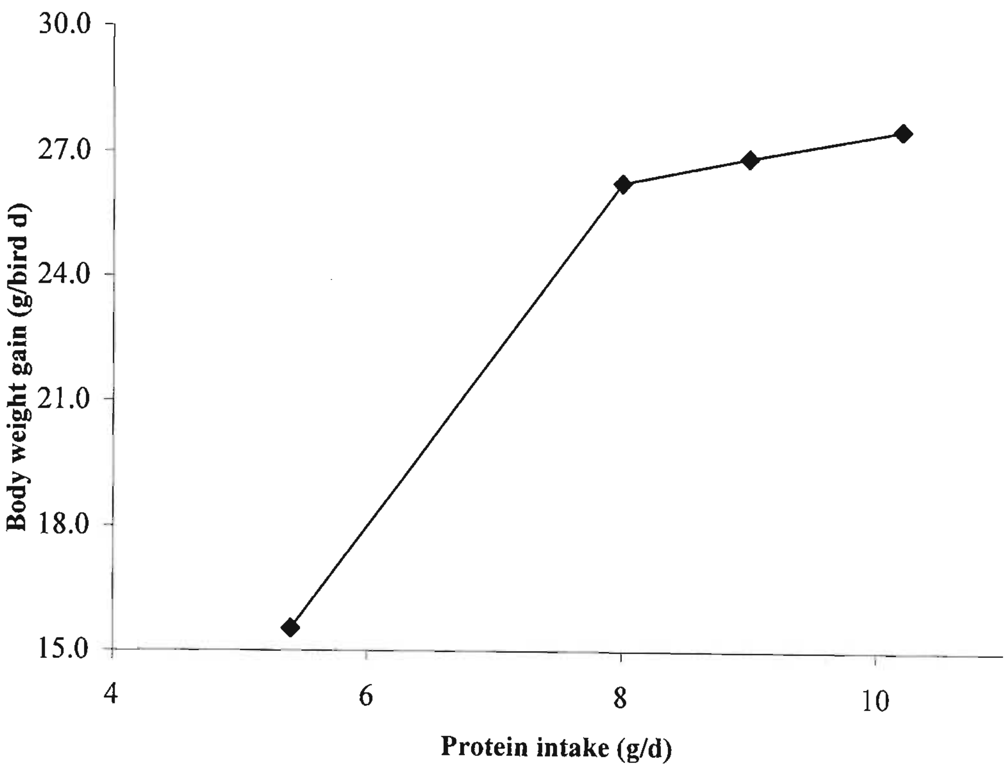

Figure 2.1 *Body weight gain of broilers fed single feeds from 0-21 d of age*

2.3.2 Feed intake

The main effects of feed consumption revealed no significant differences among treatments except for broilers on Treatments 4, 11 and 12 ($P < 0.05$). Food intake increased as the protein content was reduced, reaching a maximum on feed C and being lowest on feed D (Figure 2.2). No statistically significant differences were measured in feed intake between sexes. Food intake on feed E (feed D supplemented with L Lysine HCL) was significantly greater than on feed D, but where the broilers were given a choice between D and E (treatment 12), food intake was the same as on D alone. When broilers were given a choice between feed C and the lowest protein feed (D) food intake was lower than on any other treatment (Table 2.3).

Where broilers were given a choice of two feeds, the proportions of food chosen (Table 2.4 and Figure 2.3) varied considerably even within a treatment, with few obvious trends being evident. No choice was made when A and B were offered together, nor when B and C or C and D were offered together. In the third week of the trial, broilers preferred feeds C and D to feed A; and feed D to feed B.

2.3.3 Food conversion efficiency (FCE)

FCE increased with dietary protein content (Table 2.3 and Figure 2.2). When birds were given a choice between two feeds the resultant FCE was generally similar to that on the feed with the higher protein content, and in some cases significantly better than that on the lower protein feed. Only in the case of C vs. D was the FCE no better than on D, and with D vs. E, the FCE was no better than on D alone.

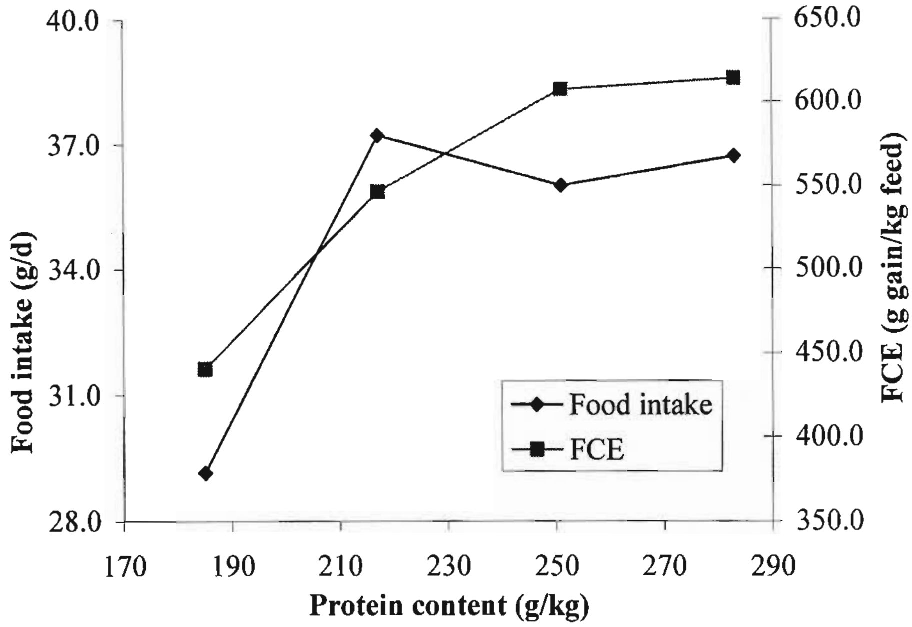

Figure 2.2 *Food intakes and feed conversion efficiency (FCE) of broilers fed single feeds from 0-21 d of age*

Table 2.4. *Proportion of one of the feeds chosen (first feed listed) each week and over the three-week period.*

TRT	0 to 7	8 to 14	15 to 21	0 - 21
A vs. B	0.48	0.46	0.48	0.47
A vs. C	0.63	0.39	0.33	0.45
A vs. D	0.55	0.45	0.29	0.43
B vs. C	0.68	0.48	0.41	0.52
B vs. D	0.66	0.47	0.38	0.51
C vs. D	0.48	0.65	0.58	0.57
D vs. E	0.63	0.76	0.65	0.68

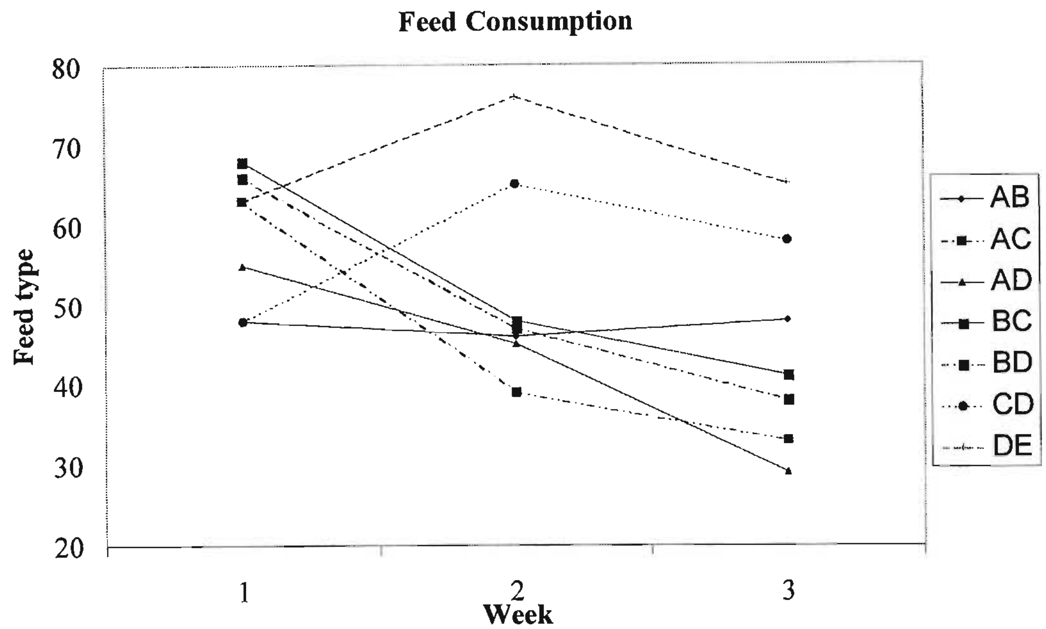

Figure 2.3 *Proportion of one of the feeds chosen (first feed listed) each week and over the three-week period.*

2.4. Discussion

The objective of this study was to determine whether broiler chickens would make an appropriate choice when presented with feeds comprising different protein levels, either by performing better than birds fed a single feed, or by exhibiting a change in the proportions of the feeds chosen over time. By supplying a range of feeds varying in protein content as single feeds and various combinations of these as choices, a more accurate analysis of the ability of a broiler to make an appropriate choice is possible. Where the feeds were offered singly, this amounted to a protein response trial, and the choice-feeding treatments could be compared with those on the response trial to determine whether appropriate choices had been made in all cases.

Performance on the protein dilution series was as expected, with body weights increasing with protein content, food intakes increasing to a maximum and then decreasing as dietary protein content was increased, and FCE showing considerable improvement with protein content, in agreement with the findings of Wethli *et al.*, (1975) which were confirmed by Boorman and Ellis (1996). What was surprising was the significant improvement in performance when synthetic lysine was added to the low protein feed: this feed was designed to be well balanced with respect to amino acids, yet the improved performance in response to additional lysine indicates that this feed was limiting in lysine. This improved growth to the addition of lysine is in line with the suggestion of Morris *et al.* (1999) that birds show a response to the addition of the first limiting amino acid. The response to additional lysine equalled that on feed treatment C, yet when the broilers were given a choice of the two feeds D and E, with or without lysine, they did not appear to differentiate between these, and performance was equal to that on the low protein feed.

Yet in all other cases but one, the performance on the choice treatments was equal to the performance on the better of the two feeds being offered. The exception was where feeds C and D were offered as a choice: in this case, the birds did not differentiate between these two feeds, and consequently the performance was no better than on the feed with the lower of the two protein contents (D). No adequate explanation can be given for this observation: in this case particularly, birds should have chosen more of C than D, as the performance on D alone was significantly poorer than on C alone. Questions arise as to whether the correct feeds were offered, or, more likely, that chicks consumed only C, but if the troughs were not continually refilled, they would have had no choice but to consume D until the troughs were again refilled. It is impossible in retrospect to determine whether this was the case.

Variation between treatments in performance was relatively high, resulting in large standard deviations and hence least significant differences (L.S.D.). For this reason, the sometimes relatively large differences in FCE between treatments, for example, proved not to be significantly different. However, the trends measured in the trial are encouraging: except in two cases, broilers chose a lower protein mixture as they aged, which conforms to the expected reduction in the requirement for protein in the feed with age. The two cases where the protein content in the mixture chosen did not diminish with time, were C *vs.* D and D *vs.* E, the latter two feeds having the same protein content. This result also suggests that the broilers could not differentiate between the low protein feeds, C and D, as mentioned above.

Where the protein content in the feed consumed diminishes over time, the protein intake is not the same as that on a feed where a constant amount of protein is included in the feed over the entire period, so comparisons between single- and choice-feeding treatments should be made with this proviso in mind.

In conclusion, the broilers in this trial responded to increases in dietary protein as expected, and the choices made by these birds were in most cases appropriate for the choice given. Performance in these cases was as good as that on the higher of the two proteins offered, and the proportion of protein in the mixture chosen diminished over time. In the two cases where the broilers did not make an appropriate choice, in one, the feeds offered were both well below the requirement for protein of a broiler of that age, and in the other the protein contents were the same, but the additional lysine appeared not to be detected by the birds. From a practical point of view, the choice that would be most appropriate for a commercial broiler producer would be that between the highest and the lowest protein feeds (A *vs.* D in this case), and in this case the broilers performed as well as those on A, and they reduced their intake of protein over time, resulting in a more economical feed than either of the two feeds on their own. From this point of view alone, there is merit in further investigating choice feeding as a means of meeting the changing amino acid requirements of broilers over time.

Chapter 3

The influence of feed form and a feed additive (Brewer's yeast) on the choices made by broilers to 21d of age

3.1 Introduction

The requirements of growing birds for dietary nutrients are expected to change with time, due to systematic changes in their requirements for maintenance and growth. The amount of food that is consumed daily by each bird increases throughout the growing period with individual variations between birds, age, and environmental factors (Michie, 1977) making it difficult to design a feeding programme that meets the requirements of all nutrients for all birds at all stages of life. Choice feeding has the potential to meet this requirement, and in the previous chapter it was shown that broilers have the potential to make the correct choice when given two feeds, a combination of which will enable them to meet their changing requirements over time. But it was shown that under some circumstances, the birds do not make an appropriate choice, and the experiment reported in this chapter explores other factors that may influence the choice made.

Feeds for young chickens are usually offered as a mash or in a crumbled or pelleted form, and some recent research by Penz (2002) has shown that broiler chickens perform better on feed that has been pelleted compared with those given mash feeds. This conforms with the conclusions made by Rose and Kyriazakis (1991) that birds select more of a cereal such as wheat when it is not ground, and even higher amounts when insoluble grit is available to the chicks. However, Savory (1974) showed that day-old chicks, probably because of its difficulty to grind within the gizzard, often avoided whole wheat.

This experiment was again designed to determine whether broilers have the ability to choose the combination of two feeds that will enable them to grow more efficiently than if only one feed is offered, but two additional choices were offered: the feeds were supplied either in a mash or a mini-pelleted (1.8mm diameter) form, and a feed additive (brewer's yeast) was included in some feeds. These two additional treatments were designed to determine whether broilers had a preference for food in a mash or a pelleted form, and whether they preferred a feed supplemented with brewer's yeast as a vitamin source. This would only have been the case had the B vitamins in the vitamin premix been below the required concentrations, which was unlikely, but it was a question posed by someone marketing brewer's yeast as a feed supplement, and this appeared to be an interesting way of testing this supposition.

3.2. Materials and methods

3.2.1 Birds and housing

Day-old sexed Ross broiler chicks were purchased from National Chicks South African ATY Ltd for this trial. Forty-eight pens were used, with ten chicks being randomly selected and placed in each pen, keeping the sexes separate. Birds were kept in these pens for the duration of the experiment from one to 21d of age. Birds were offered feed and water *ad libitum*. Single-tier broiler cages measuring 80x50cm were used. Feeders were placed inside the cages for the first ten days, and then for the rest of the experiment these were placed outside the pens. A feed saver grid was used to avoid feed wastage within each pen. A 5kg feed bin was allocated to each pen and this was filled with the test feed and then weighed at the beginning of the trial. Every seven days feed remaining in the trough was emptied into the feed bin and weighed to determine the amount of food consumed by chicks during the week. Birds were supplied with heat by means of gas heater blower, on first day, fixed at 29.5^{0}C for the first week and then reduced by 1^{0}C twice a week. The high and low temperature and humidity in the brooder room was recorded daily. The groups of birds in each pen were weighed at the start, then at 7, 14 and 21d. Also, the mortality was recorded when this occurred.

3.2.2 Diets and treatments

Two basal feeds; one high and the other low in protein were formulated (Table 3.1). These two feeds contained the same amounts of metabolisable energy (ME) and major minerals (Ca, P, Cal, K). The amino acid balance remained the same in both feeds. Brewer's Yeast, at 17g/kg, was added to half of the HP and half of the LP feeds. These four feeds were subdivided, with half remaining as mash and the other half being pelleted through a 1.8mm die. Steam was not used during the pelleting process. The eight feeds used in the trial are described in Table 3.2.

Table 3.1 *Composition (g/kg) of the two basal feeds used in the trial. Amino acids are given as totals*

Ingredient	HP		LP	
Maize	521.0		823.0	
Soybean full fat	275.0		91.5	
Soybean oilcake (460g/kg)	81.3		26.4	
Fish meal (650 g/kg)	100.0		18.3	
L-lysine HCl	0.4		2.1	
DL methionine	0.8		0.1	
Vit + mineral premix	1.5		1.5	
Limestone	10.1		17.3	
Salt	0.4		1.9	
Monocalcium phosphate	8.1		15.3	
Sodium bicarbonate	2.0		2.9	
Nutrient	Calculated	Analysed	Calculated	Analysed
Protein	250.0	250.1	130.0	130.3
AMEn (MJ/kg)	13.0	13.5	13.0	13.7
TMEn (MJ/kg)	-	14.1	-	14.1
Dry matter (%)	88.5	88.4	87.4	88.8
Threonine	8.4	10.9	4.2	4.1
Valine	10.2	17.7	5.8	7.0
Methionine	4.9	4.1	2.3	2.6
Isoleucine	9.9	15.0	4.6	5.2
Tyrosine	7.6	6.0	4.1	3.0
Phenylalanine	9.6	11.7	5.1	5.9
Leucine	19.3	24.5	12.8	12.1
Histidine	5.9	7.0	3.3	5.2
Lysine	13.7	17.6	6.9	7.6
Arginine	14.8	18.4	6.9	7.9

Table 3.2 *Description of dietary treatments used in the trial.*

Diet	Protein	Brewer's yeast	Feed form
1	High Protein (HP)	0	Mash (M)
2	HP	0	Pellets (P)
3	HP	+	M
4	HP	+	P
5	Low Protein (LP)	0	M
6	LP	0	P
7	LP	+	M
8	LP	+	P

Table 3.3 *Choice treatments imposed*

Treatment	Choice A	Choice B
1	1	2
2	1	3
3	1	4
4	1	5
5	5	6
6	5	7
7	5	8
8	2	6
9	3	7
10	4	8
11	2	8
12	3	8

A trial using the same eight basal feeds as were used in this trial was run concurrently in the same house, in which the eight feeds were fed alone (i.e. no choices were offered between them) to male and female broilers (Mabusela, 2003), and the results of these single-feed treatments were used as controls, to determine to what extent the individual feeds would have caused differences in performance.

In the trial reported here, twelve choices were offered using the eight dietary treatments described above, and these choice treatments are described in Table 3.3. The choices were designed to determine whether broilers would show a preference for one or the other of the feeds on offer, and whether this was consistent with choices made with other treatments. Choices were made between high and low protein feeds with and without the addition of Brewer's yeast, and with mash or pelleted feeds.

3.3 Results

Body weight gains, FI and FCE are given in Table 3.4. These results are from the trial conducted and reported by Mabusela (2003), which were obtained at the same time as this trial was performed.

Table 3.4 *Body weight gain, food intake and food conversion efficiency (FCE) of broilers from day-old to 21 d of age* (From Mabusela, 2003)

	Body weight gain (g/d)			Food intake (g/d)			FCE (g/kg)		
Treatment	M	F	M/F	M	F	M/F	M	F	M/F mean
1	28.6	28.7	28.7	42.0	42.6	42.3	682	674	678
2	33.1	36.3	34.7	48.9	49.4	49.1	678	735	707
3	28.4	31.2	29.8	40.9	44.3	42.6	694	706	700
4	34.1	35.7	34.9	49.7	49.6	49.6	700	720	710
5	18.4	18.4	18.4	38.7	35.7	37.2	476	516	496
6	27.7	28.0	27.9	45.3	48.7	47.0	613	575	594
7	18.4	18.9	18.6	36.0	36.0	36.0	511	524	518
8	27.1	28.6	27.9	46.7	49.9	48.3	581	574	578
SEM	1.08		0.76	1.15		0.81	22.2		15.7
LSD (0.05)	2.19		1.55	2.33		1.65	44.9		31.8

M= Male, F= Female

Of importance was the significantly improved growth rates and FCE and increased food intakes on pelleted feeds (2 *vs*. 1, 4 *vs*. 3, 6 *vs*. 5 and 8 *vs*. 7) at both protein contents, the improved performance on the high *vs*. the low protein feed, and the complete absence of a response to the addition of brewer's yeast. There were very few statistically significant differences between sexes, and as these did not appear to be related to a specific treatment, they were possibly caused by experimental error.

Table 3. 5 *Body weight, food intake and feed conversion efficiency (FCE) of broilers given 12 choice-feeding treatments from day-old to 21 d of age*

Treatment	Body weight gain (g/d)			Food intake (g/d)			FCE (g/kg)		
	M	F	M/F	M	F	M/F	M	F	M/F
1 vs. 2	31.6	30.5	31.0	48.6	45.7	47.1	650	669	659
1 vs. 3	27.3	27.8	27.5	42.2	46.0	44.1	648	604	626
1 v s. 4	30.4	33.2	31.8	44.8	47.2	46.0	677	703	690
1v s. 5	27.4	26.8	27.1	44.7	44.3	44.5	614	609	611
5 vs. 6	21.3	20.5	20.9	42.9	39.8	41.3	495	513	504
5 vs. 7	16.0	18.4	17.2	36.0	39.7	37.8	445	462	453
5 vs. 8	20.3	21.5	20.9	40.3	42.7	41.5	504	502	503
2 vs. 6	32.3	36.0	34.1	49.4	52.4	50.9	661	686	673
3 vs. 7	24.9	25.4	25.2	42.5	41.5	41.9	586	617	602
4 vs. 8	31.3	34.8	33.0	50.6	54.5	52.6	617	638	628
2 vs. 8	33.8	33.0	33.4	53.9	51.6	52.7	629	638	633
3 vs. 8	31.0	31.7	31.3	53.1	55.2	54.2	582	574	578
SEM	1.31		0.92	2.17		1.54	25.2		17.8
LSD (0.05)	2.65		1.86	4.40		3.10	51.1		35.9

M= Male, F= Female

The responses of chickens to the 12 choice-feeding treatments are given in Table 3.5. In only two cases (2 vs. 6 and 4 vs. 8) were there statistically significant (P<0.05) differences in growth rate between the two sexes. There were no differences between sexes in food intake or FCE within treatments. Differences between pelleted and mash-fed broilers disappeared when birds were given the choice between the two feed forms, i.e. they performed as well as on the pelleted feeds at both protein contents and on all choices offered. No differences in preferences were observed (Table 3.6) when birds were offered feeds with or without brewer's yeast, irrespective of the feed form or the protein content. Birds performed significantly better than those fed the low protein feeds alone, when offered a choice between a high and a low protein feed in all cases.

The broilers utilised pellets more efficiently (P<0.001) than mash feed. Feed conversion efficiency differed significantly (P<0.001) between dietary protein contents; with poor feed conversion efficiency noted when chickens were offered low protein feeds. The pelleted feed showed a greater improvement in FCE on the low- than on the high-protein feeds.

Table 3.6 *Choice A (Table 3.3) chosen by broilers as a percentage of food consumed.*

Trt	Week 1			Week 2			Week 3		
	M	F	M/F	M	F	M/F	M	F	M/F
1	79.4	73.0	76.2	31.0	32.5	31.8	31.0	34.0	32.5
2	50.3	64.7	57.5	54.0	54.5	54.3	58.0	56.0	57.0
3	84.3	77.7	81.0	24.0	23.5	23.8	22.0	21.5	21.8
4	63.0	61.8	62.4	70.0	60.0	65.0	74.5	72.0	73.3
5	78.5	86.4	82.4	67.0	80.0	73.8	39.0	45.5	42.3
6	49.0	53.5	51.3	48.5	50.0	49.3	47.5	44.0	45.8
7	79.6	74.6	51.2	58.0	46.5	52.3	35.5	33.5	34.5
8	76.5	81.0	77.1	37.0	59.5	48.3	43.5	38.5	41.0
9	66.6	66.2	66.4	62.0	64.5	63.3	73.5	68.0	70.8
10	67.4	74.4	70.9	50.5	55.0	52.8	34.0	37.5	35.8
11	68.3	73.5	70.9	50.5	54.0	52.3	36.5	35.0	35.8
12	84.0	76.0	80.0	43.0	42.5	42.8	26.0	28.5	27.3

The proportions of the two feeds selected by the broilers are given in Table 3.6, where the proportion of Choice A, as described in Table 3.3, is given for each of the sexes and weeks of the trial. The choices do not always reflect the differences that are evident in the performance when the feeds were offered singly: in all cases broilers chose more of the high protein than of the low protein feed in the first week, and this proportion diminished over time; in no instances were differences observed when broilers were given a choice between feeds either containing or without brewer's yeast; and birds tended to prefer mash feeds to pelleted feeds in the first week, although thereafter the pelleted feed was significantly preferred in all cases.

3.4 Discussion

The objective of this experiment was to determine whether broilers have the ability to choose a combination of two feeds that will enable than to be more efficient than when one feed is offered. Since no significant differences occurred between sexes, the results were combined. When broilers were offered a choice between two feeds, one of which was poorer than the other when fed alone, the broilers always performed better than on the poorer feed only: improvements were noted when broilers were offered a choice between low and high protein feeds, and between mash and pellets, but no difference when offered a choice of brewer's yeast *vs.* no brewer's yeast. In no instances did the broilers consume one food only, to the exclusion of the other, indicating that they continually tried both feeds even when one was more nutritious than the other.

The observation that birds performed better when the feed was in a pelleted form is consistent with the findings of Nir *et al.* (1995) and Penz (2002) who attributed this to the reduced maintenance requirement due to feeding pellets, as the broilers spend less time at the feeder when pellets are fed.

The highest food intake observed was on T12 (high protein mash *vs.* low protein pellets) but the food conversion by the chickens on this treatment was low, indicating that the high food intake may have been due to feed wastage. Of considerable interest was that chickens on treatments 11 and 12 initially consumed more of the high protein feed, irrespective of whether this was in the form of mash or pellets, and thereafter reduced the proportion of high protein feed consumed. This is a strong indication that broilers have the ability to make an appropriate choice when offered feeds differing in nutrient content, and that their need for protein overrides their preference for mash or pellets, even when they are more productive when fed pellets.

3.5 Conclusion

From the results of this trial it can be concluded that broiler chickens are capable of selecting a balanced diet, which closely matches their requirements, when offered two feeds, and it appears that they have different levels of preference: first, based on the nutritional quality of the food, as evidenced by their choice of the high protein food initially, followed by a preference for efficiency of utilisation of food, as evidenced by the choice of pellets rather than mash. Where the two feeds on offer supported growth. When fed alone, the broilers did not make a choice, their intake of both feeds being equal.

Chickens in this trial benefited from the use of both high protein feed and pelleted feed, but the addition of brewer's yeast had no effect on performance or feed preference.

Chapter 4

A comparison of the use of two cereals with a protein balancer offered as a choice, the choices being introduced at weekly intervals, on performance of broilers to 21d

4.1 Introduction

It has been established in the previous chapters of this thesis that broiler chickens vary in their response when offered two feeds simultaneously as a choice, the amounts of each feed chosen being influenced by such factors as the protein content of the feed, the form in which the feed is offered, and whether the birds can differentiate between the two feeds offered. In the research conducted thus far, the feeds offered, as choices did not differ significantly one from the other in terms of energy, major and minor minerals and vitamins. However, there may be a financial advantage in offering broilers a cereal and a protein balancer simultaneously, if for no reason other than that this would save the cost of grinding (Cumming, 1992). In the experiment conducted by Cumming (1992), broilers offered whole mash and a protein concentrate performed better than birds fed the mixed feed. Similarly, Nir *et al.* (1990) showed that broiler chickens perform better with mash containing coarse rather than fine particles when offered a choice.

Whether broilers would make similar choices between the cereal and the protein balancer when different cereals are used is open to question. Similarly, the choices made may differ depending on when the choice-feeding option is introduced, i.e. a broiler may choose differently in the third week after hatching if a mixed feed had been supplied to that point, compared with another which had been offered a choice of two feeds from day-old. These two questions formed the basis of the trial conducted here.

4.2 Materials and methods

4.2.1 Birds management and housing

Nine hundred and sixty sexed day-old Ross broiler chicks were obtained from a commercial hatchery and were housed in wire-floored cages in a brooder room with 96 cages, 10 chicks to a cage, with males and females being housed separately. Initial brooding temperature was 32^{0}C and this was reduced linearly to reach 24^{0}C by 21d when the trial was terminated. Chicks were provided with free access to feed and water at all times. Feeders were placed inside the cages to 14d where after larger troughs suspended outside the cages were used.

4.2.2 Feeds and feeding

A basal feed was formulated to contain nutrients at concentrations designed to meet the requirements of male broilers at 7d of age according to the EFG Broiler Growth Model, equivalent to a pre-starter feed, with the amount of cereal (maize) being fixed at 400g/kg (Table 4.1). However, maize was not included in the basal feed when this was mixed, i.e. the basal feed was a cereal-free protein concentrate.

For treatments in which a complete feed was offered the basal feed was mixed with either yellow maize meal or sorghum in the proportion 60: 40. In the choice treatments, the basal feed was offered with either maize or sorghum in separate feeders. The choice-feeding treatments were initiated at 0, 7 or 14d of age, these birds being fed the mixed feed until the choice treatment was offered. A description of the eight treatments applied is given in Table 4.2.

4.2.3 Measurements

All chicks in each cage were weighed as a group at day-old and then weekly to 21 d. Feed consumption was recorded weekly by weighing back the amount of food remaining from that allocated to each cage at the beginning of each week, account being taken of mortality. The response to the feeding treatments was assessed in terms of body weight gain (g/bird), food intake (g/bird) and food conversion efficiency (FCE). No carcass analyses were performed.

Table 4.1 *Composition (g/kg) of the basal feeds based on maize and sorghum*

Ingredients	Maize	Sorghum
Maize	400.0	
Sorghum	-	400.0
Full fat soya	474.0	474.0
Soybean oilcake meal 460	22.8	22.8
Sunflower 370	36.4	36.4
Fish meal 350	27.0	27.0
L-Lysine HCI	0.8	0.8
DL – methionine	1.3	1.3
Vitamin and mineral premix	2.5	2.5
Limestone	14.3	14.3
Monocalcium Phosphate	2.1	2.1
Sodium bicarbonate	13.9	13.9
Salt	4.4	4.4
Analysed composition (amino acids expressed as digestible)		
AMEn (MJ/kg)	14.2	13.9
TMEn (MJ/kg)	14.6	14.3
Protein	26.4	26.8
Lysine	15.7	14.8
Methionine	3.6	4.3
Arginine	17.0	18.2
Threonine	9.0	8.7
Isoleucine	11.5	11.9
Leucine	21.0	21.0
Phenylalanine	12.3	12.9
Tyrosine	6.1	6.7
Histidine	7.7	7.0
Valine	13.2	13.2

Table 4.2 *Description of the dietary treatments used in the experiment*

Treatment	Cereal used	Mixed or choice	When introduced
1	Maize	Mixed	0d
2	Sorghum	Mixed	0d
3	Maize	Choice	0d
4	Sorghum	Choice	0d
5	Maize	Choice	7d
6	Sorghum	Choice	7d
7	Maize	Choice	14d
8	Sorghum	Choice	14d

4.3 Results

Mean body weight gains (g/d), food intakes (g/d) and feed conversion efficiencies (FCE, g gain/kg food) over the three-week period are given in Table 4.3. There were no significant differences between sexes in any of the performance traits measured, and there were no differences between treatments in body weight gain. Food intake was significantly higher on treatment 5 (choice with maize introduced at 7d) than on the other treatments, with no differences between any of the remaining treatments. FCE was significantly lower on treatments 3, 5, 7 and 8 compared with the other treatments, between which there were no significant differences.

It appeared that both the cereal source and the time of introduction of the choice treatments influenced the choices made by broilers (Table 4.4). When broilers were given a choice of the cereal and balancer from day old, they consumed more of the sorghum than the maize. This preference continued throughout the trial in those chicks presented with the choice at day-old. As they aged, these broilers chose more of the cereal in both cases, the proportions increasing from 0.46 to 0.56, and from 0.62 to 0.77 in the case of maize and sorghum respectively. Where the choice treatments were introduced later, broilers chose equal proportions of maize and sorghum, and these remained constant in all periods. The main point of interest was the low proportion of maize chosen when the choice treatment was introduced in the first week, and the apparent reluctance of these broilers to increase this proportion substantially with time.

Table 4.3 *Mean body weight gain (g/d), food intake (g/d) and feed conversion efficiency (FCE, g gain/kg food)) over the three-week period*

Trt	Weight gain(g/kg)			Feed intake(g/kg)			FCE(g/kg)		
	M	F	M/F	M	F	F/M	M	F	M/F
1	29.9	31.0	30.4	43.4	43.7	43.5	691	708	700
2	31.0	30.2	30.6	47.7	44.5	46.0	652	680	665
3	29.4	26.5	27.9	47.0	45.4	46.2	632	584	608
4	28.5	29.2	28.8	47.0	45.8	44.2	672	641	656
5	28.9	30.3	29.6	52.3	54.8	53.5	564	577	571
6	28.7	30.2	29.5	43.5	45.2	44.4	658	668	663
7	28.5	31.4	30.0	46.7	48.4	47.6	612	655	634
8	29.0	28.9	29.0	50.0	46.0	48.0	584	631	607
SEM	1.71		1.21	3.68		2.60	50.2		35.5
LSD	3.48		2.46	7.46		5.28	102		72.0

M= Male, F= Female

4.4 Discussion

In order for broiler chickens to be able to grow such that they can achieve their genetic potential they need to obtain adequate amounts of the essential nutrients each day. The objective of the experiment was to determine whether the chickens would respond better to different choices of cereals, and when these were offered at different stages of growth.

Choice feeding is a useful technique for supplying animals with essential nutrients when the proportions of these nutrients in the feed change over time, as it has been shown that chickens offered a choice have the ability to select nutrients according to their requirements (Rose and Kyriazakis, 1991). However, broilers given a choice often tend to be leaner and show lower weight gains than those offered a single feed (Siegel *et al.*, 1997). This finding concurs with the results of this experiment as broilers offered maize or sorghum as a choice did, in all but one case, alter the proportion of the balancer as they aged, but also in some cases they did not perform as well as those where a complete feed was offered.

Maize and sorghum are similar in composition, so it would have been expected that the broilers would have chosen similar amounts of each when given the choice. This was the case when the choice was introduced at one and two weeks, but where the choices were offered from day old, the broilers chose significantly less of the maize than the sorghum, and this remained the case throughout the three-week period. As a result the broilers performed significantly more poorly than those fed a mixed feed with maize as the cereal source. It appears that broiler chickens do not always make appropriate choices when given the opportunity to choose from two feeds, and this may be due to the lack of direction from the parent, a lack of a training period where both feeds are offered alternately for a short period each, or simply that the chicks were unaware that a second feed was on offer. This does indicate that choice feeding may not always be successful.

Table 4.4 *Mean weekly amount of cereal chosen by male and female broilers as a proportion of total food intake, at three ages of introduction of the choice-feeding treatments*

Introduced at day	Cereal	Week1			Week 2			Week 3		
		M	F	M/F	M	F	M/F	M	F	M/F
0	M	0.47	0.44	0.46	0.57	0.44	0.51	0.57	0.55	0.56
	S	0.66	0.58	0.62	0.75	0.68	0.72	0.76	0.78	0.77
7	M				0.70	0.73	0.72	0.67	0.71	0.69
	S				0.68	0.69	0.69	0.77	0.79	0.78
14	M							0.75	0.74	0.74
	S							0.77	0.70	0.74
SEM		0.042		0.030	0.055		0.039	0.035		0.024
LSD		0.09		0.06	0.11		0.08	0.07		0.05

M= Male, F= Female

General Discussion

A characteristic of many choice-feeding experiments is that the feed selection between groups or pens within treatments is highly variable (Farrell *et al.*, 1989), so it is worth conducting more choice-feeding trials to learn more about factors that enable the birds to discriminate between the feeds on offer. The objective of the three trials reported here was to obtain more information about the choices made by broiler chickens when offered two feeds that would, in various combinations, provide the chicks with adequate amounts of the essential dietary nutrients.

In the first trial, broilers responded to increases in dietary protein as expected, and the choices made by these birds were in most cases appropriate for the choice given. Performance in these cases was as good as that on the higher of the two proteins offered, and the proportion of protein in the mixture chosen diminished over time. The appropriate choices were not made in only two cases. In the one case, broilers on the lower protein feed, when this feed was fed alone, performed significantly more poorly than those fed the higher protein feed alone, but when given a choice between the two, the intake of each was the same. This points to a management problem, where the higher protein feed was consumed and not replenished sufficiently often, resulting in the chicks being forced to consume the lower protein food. It is not possible at this stage to determine whether this was the reason for the failure of the broilers to make an appropriate choice, but seems a likely explanation. In the second case where the 'correct' choice was not made, the dietary protein contents were the same, but the additional lysine appeared not to be detected by the birds. However, in the second experiment, where broilers were offered a choice between two feeds, one of which was poorer than the other when fed alone, the broilers always performed better than on the poorer feed only: improvements were noted when broilers were offered a choice between low and high protein feeds, and between mash and pellets, but no difference when offered a choice of brewer's yeast *vs.* no brewer's yeast.

The choice feeding treatments in the third trial appeared to be successful, as broilers increased their intake of cereal as they aged, thereby reducing the protein content of the feed chosen. It appears that broilers are often capable of making the appropriate choice of dietary protein when given the opportunity to do so, but there are instances where this is not successful. The explanations given for the differences in the choices made in the third trial, when sorghum and maize were offered with a balancer, and the chicks chose significantly less of the maize than they did of the sorghum, and hence grew more slowly on the maize treatment, were: the lack of direction from the parent, a lack of a training period where both feeds are offered alternately for a short period each, or simply that the chicks were unaware that a second feed was on offer. This does indicate that choice feeding may not always be successful.

In no instances did the broilers consume one food only, to the exclusion of the other, indicating that they continually tried both feeds even when one was more nutritious than the other.

It appears that broilers need to have time after been exposed to the feeds on offer to associate the organoleptic properties of the feeds with their nutritional consequences (Rose and Kyriazakis, 1991). If this time period is long, then incorrect nutrient intakes during this stage may result in poor overall performance of the broilers, and this appeared to be the case in the third trial. In the three experiments reported here the broilers exhibited different levels of preference: in most cases the choice was based on the nutritional quality of the food, as evidenced by their choice of the high protein food initially and with this diminishing with time; the second criterion seemed to be a preference for efficiency of utilisation of food, as evidenced by the choice of pellets rather than mash. In all cases where the two feeds on offer performed equally when fed alone, the broilers did not make a choice, their intake of both feeds being equal.

As suggested by Rose and Kyriazakis (1991) there appear to be a number of factors not directly related to nutrient requirements that alter the selection made by broilers and pigs, and in some instances these factors have a profound influence on the choice made. Nutritionists and broiler producers need to be aware of these factors when advocating choice feeding as an efficient means of supplying an appropriate balance of nutrients to growing animals whose nutrient requirements vary within the population and over time. The results of the three experiments in this study on choice feeding do not provide unequivocal support for this method of feeding growing broilers.

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