Chapter 4

Replacement of Soybean Meal with Peanut Meal in Broiler Diets Containing Animal Protein Concentrate

4.1. Introduction

The availability of raw materials for feed production is the biggest challenge delaying the development of the poultry industry in Indonesia. The use of multiple protein-rich feedstuffs as dietary constituents is therefore an important means of minimising any negative effects resulting from limitations in raw materials and allowing greater flexibility in dietary formulation. Any 'supplementary effects' which improve the quality of the diet are additional benefits. Two or more feedstuffs will probably complement each other. Protein feedstuffs usually contribute the most to diet price (Nesheim *et al.* 1979; Speight 1993); accordingly, the manipulation of the use of protein source raw materials can produce economic benefit. Peanut meal is one of the alternative protein sources with high potential in Indonesia because of its availability and cost-effectiveness.

An economic evaluation using Indonesian and Australian prices of raw materials shows the economic effects of using peanut meal in broiler chicken diets. Recent Indonesian feed ingredient prices (obtained from Sinta Prima Feedmill Co., Jakarta, Indonesia) were as follow ($A/tonne): sorghum 180, soybean meal 400, peanut meal 280 and meat and bone meal (MBM) 500. Equivalent Australian raw material prices (Fielders Agricultural Products, Tamworth) were ($A/tonne): 200, 410, 640 and 420, respectively. Using these prices, and assuming constancy of price between countries for 'minor' ingredients, such as amino acids, the inclusion of peanut meal can reduce feed price in the Indonesian situation (Table 4.1); for instance, the use of 15% peanut meal lowered the feed price by $A 16.00/tonne. On the other hand, in Australian conditions, peanut meal increased the price of the diet.

Table 4.1. Diet price (based on: sorghum, soybean meal, peanut meal (PM) and meat and bone meal that represent approximately 97% of ingredients) in Australian dollars ($A) in Indonesian and Australian conditions.

%PM	0	2.5	5.0	7.5	15
$A/kg (Indonesian)	0.256	0.253	0.251	0.248	0.240
$A/kg (Australian)	0.266	0.272	0.277	0.283	0.300
Differences $A/tonne (Indonesian)	-	− 3.00	− 5.00	− 8.00	− 16.00
Differences $A/tonne (Australian)	-	+ 6.00	+ 11.00	+ 17.00	+ 34.00

Although showing price advantages, peanut meal may have some deleterious effects such as mould contamination leading to aflatoxin production, especially in warm, moist conditions. Aflatoxins will possibly produce retarded growth and poor feed conversion ratio (FCR), or even mortality with high concentrations of the toxin.

This experiment was designed to examine the effects of peanut meal in broiler chicken diets when used to replace soybean meal.

4.2. Materials and Methods

Chapter 3 provided a general description of materials and methods used throughout this thesis. This experiment used 240 birds (5 feed treatments x 6 replicates x 8 birds/cage) from 5 to 23 days of age. The number of replicates was chosen in order to minimise experimental error and to allow small differences between experimental treatments to be detected in young broiler chickens (Berndtson 1991).

Electrically-heated brooder-style cages (75 cm x 45 cm x 25 cm) were used throughout the experiment (Plate 4.1). The cages were arranged in banks of 16 (8 by 2, back to back), with 1 feeder and 1 waterer per cage.

Table 4.2. Ingredients and nutrient contents of the feed treatments in Experiment I (0, 2.5, 5.0, 7.5 and 15% peanut meal PM)).

Ingredients		0% PM	2.5% PM	5.0% PM	7.5% PM	15% PM
Sorghum	(7.1% CP)	64.26	64.09	63.91	63.75	63.23
Soybean meal	(46.7% CP)	26.30	23.48	20.66	17.83	9.37
Peanut meal	(43.3% CP)	0.00	2.50	5.00	7.50	15.00
Meat & bone meal	(49.6% CP)	7.00	7.40	7.80	8.20	9.40
Tallow		0.40	0.36	0.33	0.29	0.19
Limestone		0.43	0.42	0.41	0.40	0.36
Monocalcium phosphate		0.44	0.49	0.53	0.58	0.72
Salt (NaCl)		0.25	0.25	0.25	0.25	0.25
Sodium bicarbonate (NaHCO3)		0.15	0.19	0.24	0.28	0.41
Choline chloride (50%)		0.08	0.08	0.08	0.08	0.08
L-lysine HCl		0.13	0.17	0.20	0.24	0.35
DL-methionine		0.26	0.27	0.29	0.30	0.34
Premix*		0.30	0.30	0.30	0.30	0.30
Total		100.00	100.00	100.00	100.00	100.00

*) Commercial premix was added to provide vitamins and trace minerals

Nutrient content (calculated)	0% PM	2.5% PM	5.0% PM	7.5% PM	15% PM
Dry matter (%)	89.09	89.14	89.19	89.24	89.39
ME (MJ/kg)	12.36	12.36	12.36	12.36	12.36
(Kcal/kg)	2954	2954	2954	2954	2954
Crude protein (%)	20.7	20.71	20.71	20.71	20.71
Crude fat	3.40	3.49	3.58	3.68	3.96
Crude fibre	2.2	2.28	2.35	2.42	2.63
Ash	5.15	5.20	5.26	5.32	5.48
Ca	0.90	0.95	0.99	1.04	1.18
Total P	0.79	0.82	0.84	0.87	0.94
Available P	0.54	0.57	0.60	0.63	0.71
Na^+	0.20	0.22	0.24	0.25	0.30
Cl^-	0.25	0.25	0.26	0.26	0.27
Lysine	1.30	1.30	1.30	1.30	1.30
Methionine	0.55	0.56	0.56	0.56	0.58
Methionine + Cystine	0.87	0.87	0.87	0.87	0.87
Phenylalanine	0.95	0.96	0.96	0.96	0.96
Arginine	1.40	1.41	1.43	1.44	1.48
Tryptophan	0.25	0.24	0.23	0.23	0.21
Threonine	0.77	0.76	0.74	0.73	0.69
Isoleucine	1.00	0.97	0.95	0.92	0.85
Tyrosine	0.88	0.86	0.85	0.83	0.79
Valine	0.92	0.92	0.92	0.92	0.92
Histidine	0.50	0.49	0.49	0.49	0.47
Leucine	1.77	1.75	1.74	1.72	1.67

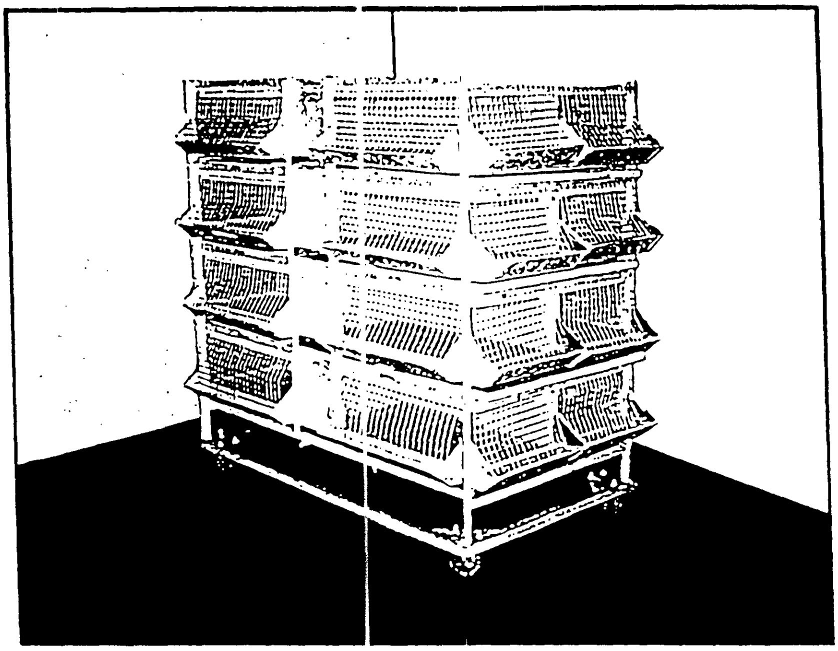

Plate 4.1. Electrically-heated cages used to house chickens during Experiment I.

Experiment I used five isoenergetic 12.36 MJ metabolisable energy (ME)/kg) and isonitrogenous (20.71% crude protein (CP)) diets formulated to broiler starter specifications (Evans 1984; NRC 1994; SCA 1987), and based on sorghum and soybean meal; typical of Australian diets (Table 4.2). Soybean meal was replaced by peanut meal (%) as follows: 0 (A), 2.5 (B), 5.0 (C), 7.5 (D) and 15 (E).

Nitrogen content of the diets and dry excreta was analysed (Chapter 3) and nitrogen digestibility value obtained as follows:

$$\text{N digestibility(\%)} = \frac{(\text{\%N feed x g FI (as fed)}) - (\text{\%N excreta x g dry excreta})}{(\text{\%N feed x g FI (as fed)})} \text{ x } 100$$

Digesta were collected from 2 chickens in each cage at 23 days of age, when the experiment ceased. Digesta from the jejunal part of the small intestine (from the end of the duodenal loop to Meckel's diverticulum) were collected. Digesta samples were centrifuged for 3 minutes and supernatants collected. The viscosity of the supernatants (500 µl) was determined using a Brookfield Viscometer model DV-1 +.

4.3. Results

The use of peanut meal to replace up to 15% of the soybean meal in a diet containing MBM as an animal protein source did not significantly affect final body weight of the birds (Table 4.3). Weight gain of the chickens showed similar patterns. Treatment E (15% peanut meal) produced a significantly ($P<0.001$) lower body weight at 12 days of age in comparison with other treatments but this was not evident at later ages.

The chickens did not significantly differ in their consumption of the diets with feed intake tending to decrease as more peanut meal was included (Table 4.3).

The inclusion of peanut meal in the diets did not significantly affect the efficiency of feed utilisation as demonstrated by FCR from 5 to 23 days of age (Table 4.3). A significant effect on FCR ($P<0.05$) was observed between 5 and 12 days of age if treatment D (10% peanut meal) is compared with treatments C (5.0% peanut meal) and E (15% peanut meal). However, treatments C and E did not differ from the diet A.

The apparent metabolisable energy (AME) values (Table 4.4) improved ($P<0.05$) above 5.0% peanut meal inclusion. The energy metabolisability of the feeds tended to increase ($P<0.10$) as peanut meal inclusion increased (Figure 4.1). The 15% inclusion

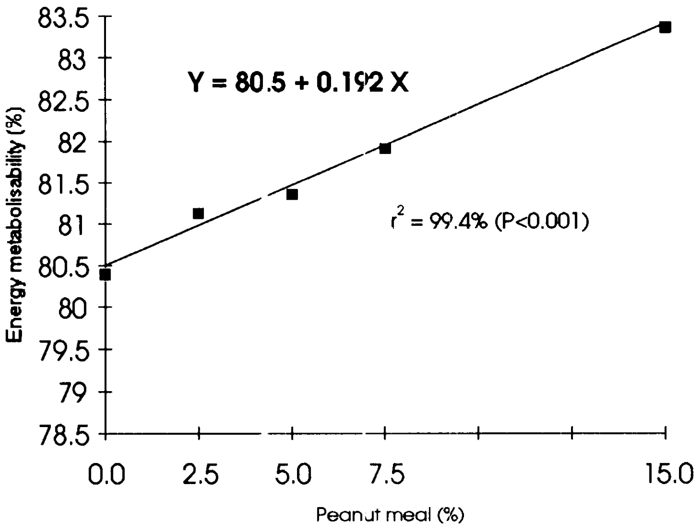

Figure 4.1. Effect of peanut meal inclusion on energy metabolisability.

Table 4.3. Effects of graded levels of peanut meal (PM) on body weight, body weight gain, feed intake and feed conversion ratio (FCR) in broilers of 5 to 23 days of age.

Diet (%PM)		A 0	B 2.5	C 5.0	D 7.5	E 15	P (%)	LSD P = 0.05
Body weight	5 d. (g)	77	78	78	78	78	27.5 NS	0.4
	12 d. (g)	240 ^{a}	237 ^{a}	235 ^{a}	241 ^{a}	223 ^{b}	0.07 ***	7.7
	19 d. (g)	540	532	519	531	522	22.9 NS	20.4
	23 d. (g)	729	714	700	713	704	23.0 NS	26.6
Body weight gain 5-23 d. (g)		652	637	623	635	626	22.2 NS	26.7
Feed intake	5-12 d. (g)	231 ^{a}	221 ^{b}	225 ^{ab}	225 ^{ab}	211 ^{c}	0.05 ***	8.1
	12-19 d. (g)	468	456	447	449	451	43.0 NS	24.8
	19-23 d. (g)	297	298	289	291	301	63.3 NS	17.9
	5-23 d. (g)	996	975	962	965	963	46.0 NS	43.2
FCR	5-12 d.	1.43 ^{ab}	1.39 ^{bc}	1.44 ^{a}	1.38 ^{c}	1.45 ^{a}	3.76 *	0.050
	12-19 d.	1.56	1.56	1.58	1.55	1.53	87.4 NS	0.096
	19-23 d.	1.58	1.64	1.60	1.61	1.66	34.7 NS	0.087
	5-23 d.	1.53	1.54	1.55	1.52	1.54	93.2 NS	0.070

NS = $P>0.10$

– = $0.05<P<0.10$

Means within a row with different superscripts are significantly different ($P<0.05$)

Table 4.4. Effects of graded levels of peanut meal (PM) on apparent metabolisable energy (AME), nitrogen digestibility, digesta viscosity, excreta moisture and dry excreta weight in broilers.

Diet (%PM)	**A** 0	**B** 2.5	**C** 5.0	**D** 7.5	**E** 15	**P** (%)	**LSD** P = 0.05
AME (MJ/kg as fed)	12.30^{a}	12.43^{ab}	12.53^{abc}	12.79^{c}	12.70^{bc}	2.60 *	0.317
Nitrogen digestibility (%)	64.1	66.5	68.0	66.1	66.4	54.0 NS	4.60
Digesta viscosity (cP)	2.13	1.95	1.82	1.98	1.83	68.8 NS	0.496
Excreta moisture (%)	59.9	57.7	61.6	58.5	64.2	71.4 NS	10.44
Dry excreta (g)	61.2	59.5	57.1	56.9	54.5	25.1 NS	6.29

NS = P>0.10
– = 0.05<P<0.10
Means within a row with different superscripts are significantly different (P<0.05)

of peanut meal in the diet resulted in a 3.73% higher energy metabolisability than that of the diet without peanut meal. A significant relationship existed between energy metabolisability and peanut meal inclusion, as shown above (Figure 4.1).

Nitrogen digestibility values were similar on all diets (Table 4.4).

No differences were observed in the digesta viscosity, excreta moisture contents and the amount of dry excreta (Table 4.4), although diet A produced an increase in dry excreta of 12.3% compared with the diet E (15% peanut meal; Table 4.4).

Total mortality (including culling) of the chickens during experiment was 1, 2, 1 and 4 for diets A, B, C and E, respectively

4.4 Discussion

The cumulative growth and feed intake of the birds did not differ among feed treatments. However, peanut meal-fed birds tended to have a slower growth and lower feed intake than soybean meal-fed birds. The use of 15% peanut meal significantly ($P<0.001$) reduced body weight and body weight gain of the birds between 5 and 12 days. In addition, feed intake was significantly ($P<0.001$) reduced by feeding peanut meal diets during this period. The effects of alternative plant protein meal usage on performance are usually more severe in the earliest stages of chicken development (Bartlett 1974; Peters & Yule 1974) and may be due to lower amino acid availabilities in peanut meal (Table 2.10) in this experiment.

It is unlikely, however, that the reduced performance of the birds was caused by the aflatoxin content of the peanut meal. Mould contamination and associated toxins can decrease nutrient utilisation (amino acid digestibility) by the birds and cause loss of appetite (Evans 1985; Curtis 1990), and hence a reduced growth rate or poor level of performance. In this experiment, the greatest level of peanut meal inclusion (15%) was higher than that recommended by Sainsbury (1984), i.e. 10% peanut meal in the feed. The peanut meal obtained for these experiments contained less than 75 µg/kg aflatoxin. Therefore, the maximum peanut meal inclusion level resulted in less than 11.25 µg/kg aflatoxin in the diet. Say (1987) considered that an aflatoxin content of less than 1,250 µg/kg in peanut cake is usable in the tropics. Speight (1993) noted the lower maximum aflatoxin contents permitted in peanut products and complete feed for chicks in the UK were 20 and 10 µg/kg, respectively The climatic conditions and agronomic practices in Australia suggest that mycotoxin is not a major problem (Bryden 1989). Excreta moisture contents for all birds were comparable, also suggesting that there was no mould and aflatoxin contamination or anti-nutritional factor in the peanut meal used.

The 15% peanut meal diet had a slightly lower moisture content than did the soybean meal diet (Appendix 1) which may have reduced feed intake through reduced palatability. Similarly, the commercial broiler chicken diet that had been used before the experiment began did not contain peanut meal, and it is possible that an adaptation time is needed for the introduction of any new raw material, or in fact, diet.

According to North and Bell (1990), a chicken has fewer taste buds than a mammal, but its ability to taste feeds is relatively high. There were no palatability problems observed when broiler cockerels were offered diets containing up to 15% sunflower meal, replacing soybean meal (Yule 1974); in contrast, in this experiment, feed consumption was decreased with the use of peanut meal, probably because of palatability problems.

Several factors may be involved. The skin of the peanut, 3% of the seed weight, contains high levels of tannin and has a bitter taste which may have reduced feed intake (Evans 1985). Göhl (1981) indicated that expelled oilseed products may develop a rancid, bitter taste after a few weeks of storage because of their residual oil content. Oxidation of the oil causes destruction of vitamins and possibly loss of amino acids (Shafey 1993). Rancid meals will also cause diarrhoea in birds (Evans 1985).

The higher fibre content of peanut meal, due particularly to the inclusion of immature pods and seed hulls, may increase protein loss from the body, increase rate of passage of the food through the gut, decrease the time available for digestion (Dingle 1992), and influence the digestibility and availability of amino acids (Austic 1983). Tannins, in the skin of the peanut, appear to increase the output of endogenous proteins (Green *et al.* 1973; Rostango *et al.* 1973). It seems that the lower feed consumption by the birds in the early stage of the experiment also affected the body weight achieved.

There were no differences between diet treatments on FCR between 5 and 23 days of age. Differences (P<0.05) appeared between 5 and 12 days when 7.5% peanut meal-fed birds achieved the best conversion, followed by 2.5, 0, 5.0 and 15% peanut meal inclusion. However, the highest level of peanut meal inclusion produced similar FCR to the 5.0% and nil peanut meal treatments. In essence, up to 15% peanut meal can be used, replacing soybean meal, in diets containing MBM without adversely affecting the birds' performance.

The gross energy analyses of the diets produced similar results between diets (Appendix 1). However, the AME values of the diets significantly (P<0.05) improved above 5% peanut meal inclusion. Energy metabolisability also tended to improve (P<0.10) when peanut meal was incorporated into the diets (Figure 4.1).

Peanut meal has a slightly higher ME value, because of its fat content, than soybean meal. With the increased inclusion of peanut meal, the total fat contents of the diets increased from 3.40 to 3.96%, even though the use of tallow decreased from 0.40 to 0.19%. This indicates that peanut meal may be more digestible in terms of energy. The increase in crude fibre content in the diets, from 2.21 to 2.63%, is within the tolerance of broiler chickens (Göhl 1981).

The soybean meal-based diet, furthermore, tended to produce lower nitrogen digestibility value than did peanut meal-supplemented diets. Vohra (1993) indicated that when combinations of proteins were needed to balance the amino acid requirements such as soybean/peanut meal-based diet, they also produced a biological value higher ('supplementary effects') than that of diets where one protein source was used.

The normal digesta viscosity value for sorghum-based diets is about 2 centipoise (cP) (Choct *et al.* 1996). High digesta viscosity values indicate high levels of undigested polysaccharides in the feed, and hence a digestion problem. From the digesta viscosity data, peanut meal diets produced lower values than did soybean meal diet. It can therefore be concluded that peanut meal does not contain a significant amount of soluble non-starch polysaccharides (NSPs).

Because the protein and amino acid components of a diet are relatively expensive (Nesheim *et al.* 1979; Speight 1993), the efficient use of protein is crucial in poultry meat production. The use of peanut meal, the price of which is approximately half that of soybean meal in Indonesia, can reduce the serious difficulty of not only obtaining adequate supplies, particularly of proteinaceous feedstuffs, for feed production in that country, but also reducing the costs of feed. There is no economic advantage in using peanut meal in Australian conditions; however, the prices of raw materials as well as availability will change from time to time. Soybean meal is presently in short supply in Australia, as is reflected in the current price.

Broilers fed a diet containing soybean meal as the sole protein concentrate showed significantly poorer growth than broilers fed any of a number of the alternative diets (Yule 1974; Irish & Balnave 1991, 1993a, b). It has been previously shown that soybean meal can be partly or totally replaced by alternative protein sources (starter diet/finisher diet), such as cottonseed meal (10.9%/6.2%), safflower meal (12.0%/7.0%), rapeseed meal (8.3%/4.9%), coconut meal (29.7%/16.4%) (Bartlett 1974); rapeseed meal (10%) (Koentjoko 1974); sunflower meal (nil to all) (Wilson & MacAlpine 1974) and sunflower meal (7.5%) (Yule 1974).

Moreover, the use of some 'alternative' protein ingredients in the replacement of soybean meal has been studied more recently: sesameseed meal (5%) in starter diet (Wanasuria & Hutagalung 1989); canola meal (15%) (Solminski & Campbell 1990); sunflower meal or mixture of sunflower meal and either meat meal or poultry offal meal (Irish & Balnave 1991); sunflower meal (7.5%), rapeseed meal (7.5%), cottonseed meal (7.5%) (Irish & Balnave 1993a, b) and canola meal (Kumar *et al.* 1995) (Table 2.6).

Göhl (1981) indicated that the protein composition of peanut meal is far more variable than that of soybean meal. Peanut meal is deficient in the sulphur amino acids and also lysine (Miller 1976; Evans 1985). The nutritive values, i.e. biological value, chemical score, protein efficiency ratio and gross protein value of peanut meal (Table 2.9) were all lower compared with soybean meal (McDonald *et al.* 1988). Peanut meal has poorer amino acid profiles (Table 2.8), most notably lysine, isoleucine and methionine

+ cystine in sorghum-based diets and lower amino acid digestibility as well (Table 2.10), particularly glycine, lysine, cystine and histidine (Rhône-Poulenc 1993), so that supplementation by synthetic amino acids in the diet may be required. In brief, the protein quality of peanut meal is generally inferior to that of soybean meal. However, it seems from the current experiment that peanut meal can also replace soybean meal in broiler chicken starter diets.

Chapter 5

Use of Peanut Shell as a Feed Source for Broiler Chickens

5.1. Introduction

Peanut shell is an agricultural by-product not normally used as feed, particularly for broilers, because of its high fibre content. This by-product is readily available in tropical countries but is usually treated as waste. With the production of peanut on the increase, peanut shell can perhaps be used if its nutrient contents are clearly characterised. There is no doubt that the utilisation of peanut shell would reduce the price of the feed as shown in Table 4.1. Furthermore, agricultural by-products may be used as replacement of traditional feedstuffs.

Fibre is an indigestible component of the feed (McDonald *et al.* 1988); however, its importance in the poultry and feed production systems should not be ignored. Excessive levels of fibre may result in increased feed intake and lower digestibility of the diet. Moreover, the quality of pelleted or crumbled feed and the capacity of feed production will be affected by the level of fibre in the feed compounds. Dusty feed related to excess fibre will possibly decrease feed intake and increase feed scattering. Therefore, the feed efficiency may decline when the fibre content of feed rises.

This experiment was conducted to examine the use of peanut shell as an alternative feed source in broiler diets.

5.2. Materials and Methods

Experiment II used 200 broilers from 6 to 24 days of age. These birds were divided into 5 feed treatments x 5 replicates x 8 birds/cage.

This experiment employed 25 individual brooder cages (60 cm x 34 cm x 24 cm) utilising a thermo-lamp rather than an electric bar heater (Plate 5.1). These cages were furnished with 2 feeders (of which only 1 was used) and 1 waterer, and were extended in height from 24 cm to 32 cm when the birds reached 16 days of age. The chickens were then moved to Harrison carry-on cages (75 cm x 75 cm x 38 cm) when they reached 20 days of age (Plate 5.1). The larger cages were arranged in banks of 8 and each had 1 feeder and 1 waterer. The cages were unheated and a fan heater was used to achieve required room temperatures.

Five isoenergetic (12.50 MJ ME/kg) and isonitrogenous (21.50% CP) diets were used (Table 5.1), and contained different levels of peanut shell (%): 0 (A), 1.13 (B), 2.25 (C), 4.5 (D) and 9.0 (E). These diets were based on a sorghum and soybean meal diet as previously used (Chapter 4). The crude fibre contents of the diets ranged from 2.08 to 7.26% (Table 5.1).

The AME value of peanut shell was determined by dilution of a commercial broiler finisher mash diet (Fielders Agricultural Products, Tamworth). The mixed diets were crumbled to prevent avoidance of the peanut shell by the birds.

The abdominal fat pad (excluding the fat surrounding the gizzard) from 4 birds per cage was removed and weighed after cervical dislocation of the birds at 24 days of age.

Crude fibre contents of peanut shell and the five diets were also determined (Helrich 1990; Furda 1993).

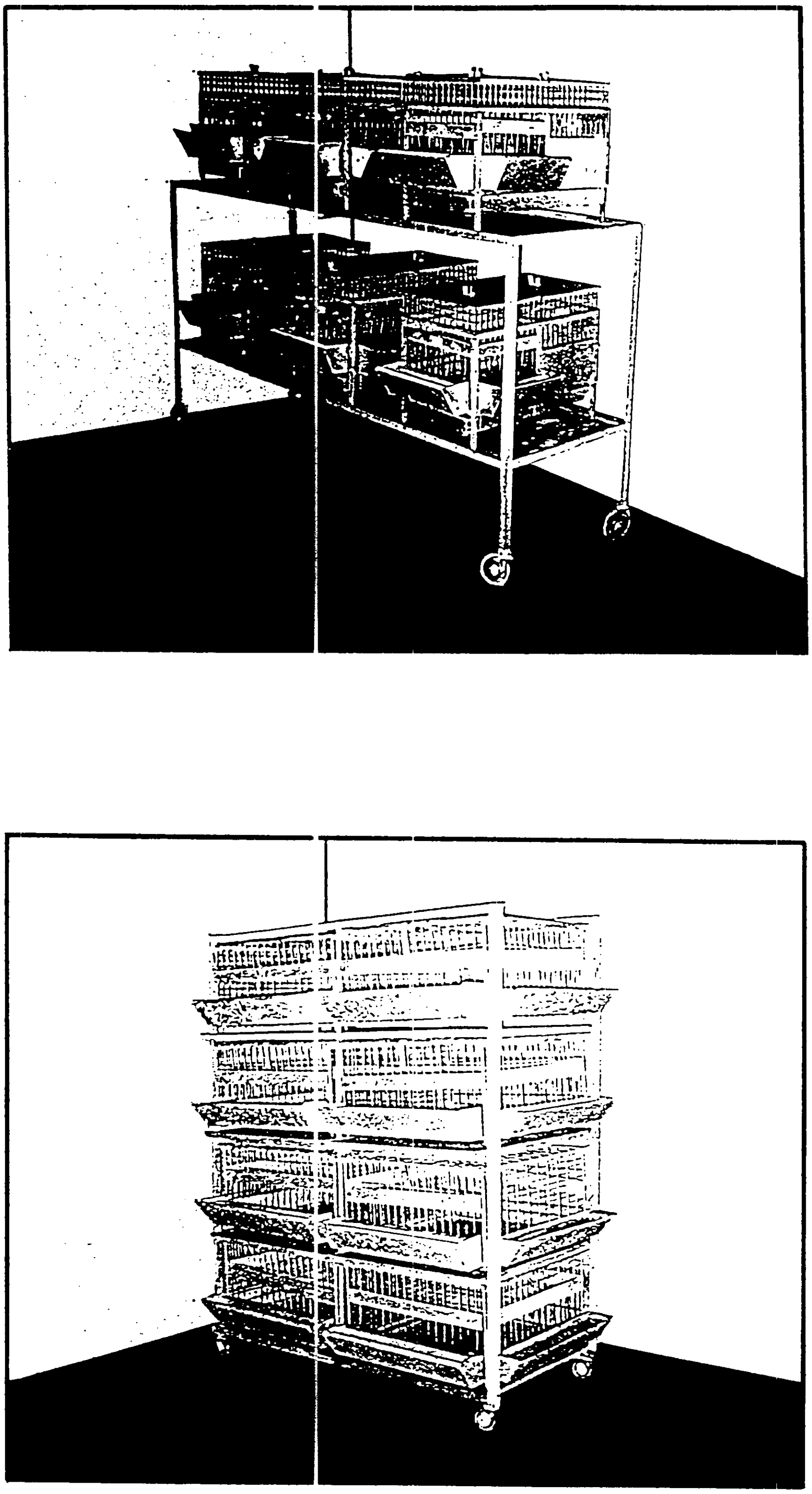

Plate 5.1. Individual thermo-lamp cages (above) and Harrison carry-on cages (below) used to house chickens during Experiment II.

Table 5.1. Ingredients and nutrient contents of the feed treatments in Experiment II (0, 1.13, 2.25, 4.5 and 9.0% peanut shell (PS)).

Ingredients		0% PS	1.13% PS	2.25% PS	4.5% PS	9.0% PS
Sorghum	(7.1% CP)	65.36	63.58	61.82	58.29	51.25
Soybean meal	(46.7% CP)	21.13	21.22	21.31	21.49	21.84
Peanut shell		0 00	1.13	2.25	4.50	9.00
Meat & bone meal	(49.6% CP)	3 00	3.00	3.00	3.00	3.00
Fish meal		8 00	8.00	8.00	8.00	8.00
Tallow		0 00	0.63	1.25	2.50	5.00
Limestone		0 49	0.46	0.44	0.39	0.29
Monocalcium phosphate		0 88	0.84	0.79	0.69	0.50
Salt (NaCl)		0 25	0.25	0.25	0.25	0.25
Sodium bicarbonate (NaHCO3)		0 09	0.09	0.09	0.09	0.09
Choline chloride (50%)		0 08	0.08	0.08	0.08	0.08
L-lysine HCl		0 04	0.04	0.03	0.03	0.01
DL-methionine		0 18	0.18	0.19	0.19	0.19
Premix		0 50	0.50	0.50	0.50	0.50
Total		100 00	100.00	100.00	100.00	100.00

Nutrient contents	0% PS	1.13% PS	2.25% PS	4.5% PS	9.0% PS
Dry matter (%)	87 16	87.32	87.47	87.79	88.41
ME (MJ/kg)	12 50	12.50	12.50	12.50	12.50
(Kcal/kg)	2988	2988	2988	2988	2988
Crude protein (%)	21 50	21.50	21.50	21.50	21.50
Crude fat	3 00	3.59	4.17	5.35	7.69
Crude fibre	2 08	2.73	3.37	4.67	7.26
Ash	5 25	5.25	5.25	5.26	5.26
Ca	1 06	1.04	1.03	0.99	0.93
Total P	0 86	0.85	0.84	0.81	0.76
Available P	0 64	0.63	0.62	0.60	0.56
Na^+	0 20	0.20	0.20	0.20	0.20
Cl^-	0 30	0.30	0.30	0.30	0.29
Lysine	1 30	1.30	1.30	1.30	1.30
Methionine	0 55	0.55	0.55	0.55	0.55
Methionine + Cystine	0 87	0.87	0.87	0.87	0.87
Phenylalanine	1 00	1.00	1.00	1.00	0.99
Arginine	1 34	1.35	1.35	1.36	1.37
Tryptophan	0 26	0.26	0.26	0.25	0.25
Threonine	0 82	0.82	0.82	0.82	0.82
Isoleucine	1 05	1.05	1.05	1.04	1.04
Tyrosine	0 91	0.90	0.90	0.89	0.87
Valine	0 98	0.98	0.98	0.97	0.97
Histidine	0 53	0.53	0.53	0.53	0.53
Leucine	1 84	1.83	1.82	1.81	1.77

5.3. Results

The birds responded similarly as indicated by their final body weights (24 days of age) regardless of the level of peanut shell inclusion (Table 5.2) and no significant effect on weight gain was observed when up to 9.0% peanut shell was included.

Feed intake was not significantly affected by the dietary treatments even though peanut shell inclusion tended to increase feed consumption of the birds.

Peanut shell inclusion did not have any significant effects on FCR as would be expected given the body weight and feed intake data (Table 5.2).

The AME content of peanut shell was 3.87 MJ/kg dry matter (DM); however, when incorporated into the diets, the AME values tended to rise ($P<0.05$) with the increased level of peanut shell inclusion (Table 5.3) from 14.60 MJ/kg DM (diet A: 0% peanut shell) to 14.93 MJ/kg DM (diet E: 9.0% peanut shell). In contrast, peanut shell significantly ($P<0.001$) reduced the energy metabolisability of the diets. Diet E had 5.8% less energy metabolisability than diet A.

The moisture content of excreta (Table 5.3) was significantly reduced ($P<0.05$) with the inclusion of peanut shell. Birds fed diet E produced drier (9% less moisture content) excreta than those on diet A. The amount of dry excreta produced was significantly ($P<0.001$) affected by the dietary treatments.

The use of peanut shell resulted in a non-significant increase in the amount of abdominal fat (Table 5.3). The size of abdominal fat of diet A-fed birds was only 85% of that of birds fed diet E.

Mortality during the experiment was very low (3 birds in total) and was not related to dietary treatments.

Table 5.2. Effects of graded levels of peanut shell (PS) on body weight, body weight gain, feed intake and feed conversion ratio (FCR) in broilers of 6 to 24 days of age.

Diet (%PS)		A 0	B 1.13	C 2.25	D 4.5	E 9.0	P (%)	LSD P = 0.05
Body weight	6 d. (g)	102	102	102	102	102	6.2 –	0.2
	12 d. (g)	249	273	279	283	283	13.1 NS	10.1
	18 d. (g)	553 ^{a}	520 ^{b}	544 ^{a}	558 ^{a}	558 ^{a}	1.13 *	22.4
	21 d. (g)	705 ^{a}	667 ^{b}	687 ^{ab}	711 ^{a}	713 ^{a}	2.27 *	30.5
	24 d. (g)	852	819	851	850	867	10.3 NS	34.6
Body weight gain 6-24 d. (g)		750	717	748	749	765	10.3 NS	34.6
Feed intake	6-12 d. (g)	228	221	227	225	223	61.8 NS	10.2
	12-18 d. (g)	357 ^{a}	341 ^{b}	357 ^{a}	368 ^{a}	361 ^{a}	1.39 *	14.3
	18-21 d. (g)	244	242	243	257	253	37.5 NS	17.9
	21-24 d. (g)	241	239	248	241	251	28.8 NS	13.4
	6-24 d. (g)	1070	1043	1075	1090	1088	20.3 NS	43.3
FCR	6-12 d.	1.25 ^{a}	1.30 ^{b}	1.29 ^{b}	1.27 ^{ab}	1.24 ^{a}	2.86 *	0.039
	12-18 d.	1.33	1.40	1.34	1.34	1.32	23.0 NS	0.069
	18-21 d.	1.60	1.66	1.75	1.68	1.63	56.2 NS	0.186
	21-24 d.	1.64	1.58	1.54	1.74	1.63	24.8 NS	0.180
	6-24 d.	1.43	1.46	1.44	1.46	1.43	13.7 NS	0.038

NS = $P>0.10$

– = $0.05<P<0.10$

Means within a row with different superscripts are significantly different ($P<0.05$)

Table 5.3. Effects of graded levels of peanut shell (PS) on apparent metabolisable energy (AME), energy metabolisability, excreta moisture, dry excreta weight and abdominal fat pad in broilers.

Diet (%PS)	A 0	B 1.13	C 2.25	D 4.5	E 9.0	P (%)	LSD P = 0.05
AME (MJ/kg DM)	14.60 ^{a}	14.72 ^{ab}	14.89 ^{bc}	14.74 ^{abc}	14.93 ^{c}	1.72 *	0.196
Energy metabolisability (%)	90.1 ^{a}	90.6 ^{a}	90.1 ^{a}	87.4 ^{b}	84.9 ^{c}	0.00 ***	1.19
Excreta moisture (%)	64.8 ^{a}	65.1 ^{a}	64.8 ^{a}	63.0 ^{ab}	59.0 ^{b}	4.16 *	4.31
Dry excreta (g)	54.3 ^{a}	54.3 ^{a}	57.9 ^{b}	60.5 ^{b}	69.5 ^{c}	0.00 ***	3.52
Abdominal fat pad (%)	0.79	0.84	0.87	0.89	0.93	30.8 NS	0.142

NS = $P>0.10$

– = $0.05<P<0.10$

Means within a row with different superscripts are significantly different ($P<0.05$)

5.4 Discussion

Peanut shell is not normally utilised in broiler diets because of its high fibre content and bulkiness. Laboratory analyses of peanut shell indicated that it contains approximately 64% crude fibre (DM) (Appendix 1), contributing 4.85% additional crude fibre in the 9% peanut shell diet.

The use of 9% peanut shell in the diet did not affect body weight and weight gain of the chickens, or feed intake. However, feed intake tended to increase as peanut shell inclusion rose, as would be expected because of the increase in dietary fibre content.

The utilisation of many feedstuffs by poultry may be limited by the lack of endogenous enzymes necessary for hydrolysis of dietary components (Classen & Campbell 1990). The optimum crude fibre content of chick grower feed is about 3% (Göhl 1981). The diets used in this experiment contained 2.51 to 7.36% crude fibre. In many cases, however, crude fibre is a misleading indicator of the digestibility and nutritive value of the feed (Göhl 1981; Janssen & Carré 1989), although Austic (1983), Farrell *et al.* (1983) and Parsons (1993) showed that the presence of high levels of fibre in ingredients is one factor which affects low digestibility and availability of amino acids. Rhône-Poulenc (1993) indicated that the lower true amino acid digestibility of cereal by-products, for instance wheat bran, is probably related to higher fibre and ash content. Similarly, Göhl (1981) observed that dietary peanut hull inclusion interferes with digestion, and especially protein digestion, unless it is fed in very small amounts. The data obtained in this experiment, however, do not support the above assertions with respect to peanut shell inclusion, as bird performance (growth rate and FCR) was not affected by the inclusion of peanut shell.

However, the increased inclusion of tallow from 0 to 5%, or total fat from 3 to 7.69% in the diet, to offset the lower availability of energy due to peanut shell inclusion, may have offset any negative effects on body weight (Carew, Jr. *et al.* 1963). This assertion is supported by the AME data. The AME values tended to increase ($P<0.05$) when peanut shell inclusion rose, although the energy metabolisability of the diets was greatly ($P<0.001$) reduced.

Usually high fibre diets are low in energy and in fat content, but excretion of bile acids, which is important in fat absorption, is apparently increased in the presence of dietary fibre (Eastwood 1973; Kritchevsky 1976). Therefore, it is possible that the AME of the peanut shell diets was higher than that of the diet without peanut shell due to a combination of both the tallow and peanut shell inclusions.

Unconventional waste by-products may be utilised if traditional feedstuffs are inadequate or unavailable. Many factors that have to be considered in using these materials include the possibility of mould contamination and associated toxins (Sanders *et al.* 1984) due to improper handling. Also, during harvesting and processing other contamination may take place, so that the purity of these ingredients, such as peanut shell, may be greatly reduced (Nitis 1983). Waste by-products may also contain toxic residues from insecticides, fertilisers, processing chemicals or fungal growth (Farrell *et al.* 1983).

An important finding in this study was that inclusion of peanut shell reduced ($P<0.05$) the moisture content of the excreta, albeit the total excreta volume was not decreased. Wet and sloppy droppings are a major problem in the poultry industry, causing environmental pollution (Bell 1974), poor health and carcass quality in broilers (Classen & Campbell 1990; Carré & Melcion 1995) and dirty eggs and shed problems in layers. Any reduction in excreta moisture, therefore, is both economically and environmentally significant for this industry.

The use of peanut shell, a product that has little or no market value, will possibly reduce the feed price. In this study the inclusion of up to 9% peanut shell did not reduce the performance of broiler chickens.

Chapter 6

Interaction between Peanut Meal and Different Cereal Grains in Broiler Diets

6.1. Introduction

The first essentials for the provision of correct, complete and balanced diets are that they should contain the appropriate amount and proportion of energy and protein. Energy source raw materials usually contribute the biggest proportion of a diet (more than 60%), and should be considered as an important production cost factor since their cost represents the biggest part of the total cost of production. It is therefore vital that the diets should be affordable. From a practical standpoint, the efficient use of protein (and secondly energy) is critical for economical production of poultry meat. Alternative energy and/or protein source raw materials are crucial to fulfill the high demand of nutrient requirements of meat chickens. Moreover, the interaction between some kinds of energy and protein sources should be taken into account.

From Experiment I, peanut meal was found to be a promising protein-rich feedstuff in the broiler diet so that the interaction of this raw material and other feed ingredients may prove to be valuable. Choct and Annison (1990a, b) found that using different energy sources with similar dietary protein sources, the performance of broilers differed. The aim of the following experiment was to determine the interaction between some cereal grains commonly used in Australia, and peanut meal.

6.2. Materials and Methods

A total of 240 birds were allocated to 5 treatments with 6 replicates of 8 birds.

Chickens were housed in electrically-heated brooders (Plate 4.1) until 21 days of age, after which the birds were housed in larger carry-on cages (Plate 5.1). No supplementary heating was used after 21 days of age.

The mash diets used for this trial were isoenergetic (12.50 MJ ME/kg) and isonitrogenous (20.50% CP), containing different energy sources in combination with soybean meal or peanut meal as protein sources (Table 6.1). These diets were: A (soybean meal/sorghum), B (peanut meal/sorghum), C (peanut meal/barley), D (peanut meal/maize) and E (peanut meal/wheat).

Digesta samples were obtained from 2 chickens in each cage at 26 days of age. Digesta were taken from the ileal part of the small intestine (from Meckel's diverticulum to 5 cm above ileo-caecal junction). The samples were centrifuged at 12,000 *g* for 10 minutes, then the supernatants were collected and frozen (-25°C). The viscosity of the supernatants was determined 5 days after collection using a Brookfield Viscometer.

Bulk density of the diets in this experiment was measured using a cylindrical flask of one Litre volume. Feed was poured through a funnel until it reached volume whereupon the weight of the feed was determined.

Table 6.1. Ingredients and nutrient contents of the feed treatments in Experiment III (soybean meal (SBM)/sorghum, peanut meal (PM)/sorghum, PM/barley, PM/maize and PM/wheat).

Ingredients		SBM/S	PM/S	PM/B	PM/M	PM/W
Sorghum	(9.3% CP)	67 17	64.56	0.00	0.00	0.00
Barley	(9.3% CP)	0 00	0.00	60.53	0.00	0.00
Maize	(7.0% CP)	0 00	0.00	0.00	63.98	0.00
Wheat	(11.2% CP)	0 00	0.00	0.00	0.00	65.98
Soybean meal	(46.7% CP)	20 00	0.00	0.00	0.00	0.00
Peanut meal	(43.3% CP)	0 00	20.00	20.00	20.00	20.00
Meat & bone meal	(49.6% CP)	0 66	1.75	2.77	5.08	0.00
Fish meal		6 50	6.50	6.50	6.50	5.74
Tallow		0 85	0.81	7.42	0.58	3.98
Limestone		0 86	0.67	0.36	0.36	0.68
Monocalcium phosphate		2 26	1.99	0.97	1.03	1.97
Salt (NaCl)		0 25	0.25	0.25	0.25	0.25
Sodium bicarbonate (NaHCO3)		0 15	0.08	0.08	0.04	0.14
Choline chloride (50%)		0 08	0.08	0.08	0.08	0.08
L-lysine HCl		0 13	0.42	0.29	0.31	0.43
DL-methionine		0 19	0.29	0.25	0.22	0.25
Premix		0 50	0.50	0.50	0.50	0.50
Cellulose filler (solkafloc)		0 40	2.10	0.00	1.07	0.00
Total		100 00	100.00	100.00	100.00	100.00

Nutrient contents	SBM/S	PM/S	PM/B	PM/M	PM/W
Dry matter (%)	85 20	85.63	88.96	86.42	87.37
ME (MJ/kg)	12 50	12.50	12.50	12.50	12.50
(Kcal/kg)	2988	2988	2988	2988	2988
Crude protein (%)	20 50	20.50	20.50	20.50	20.50
Crude fat	3 45	4.22	10.25	4.85	6.26
Crude fibre	2 42	4.69	5.56	4.04	3.11
Ash	4 63	4.52	5.05	4.77	3.92
Ca	1 20	1.20	0.97	1.18	1.03
Total P	0 95	0.93	0.79	0.90	0.86
Available P	0 72	0.72	0.58	0.71	0.62
Na^+	0 20	0.20	0.20	0.20	0.20
Cl^-	0 27	0.28	0.32	0.27	0.20
Lysine	1 25	1.25	1.25	1.25	1.25
Methionine	0 54	0.57	0.53	0.54	0.53
Methionine + Cystine	0 86	0.86	0.86	0.86	0.86
Phenylalanine	0 98	1.00	0.98	0.95	0.97
Arginine	1 25	1.37	1.49	1.47	1.44
Tryptophan	0 25	0.20	0.20	0.18	0.21
Threonine	0 75	0.65	0.67	0.68	0.63
Isoleucine	0 98	0.80	0.77	0.77	0.76
Tyrosine	0 77	0.69	0.64	0.66	0.65
Valine	0 94	0.93	0.94	0.92	0.88
Histidine	0 49	0.46	0.48	0.50	0.48
Leucine	1 88	1.76	1.36	1.61	1.35

6.3. Results

The use of the various cereal grains caused different (P<0.001) body weights from an early age (Table 6.2) and the pattern of growth by the birds on each treatment was consistent (Figure 6.1). Birds fed soybean meal/sorghum (diet A) produced the heaviest final body weight (26 days of age) compared with the combinations of peanut meal and different cereal grain diets. In peanut meal diets, sorghum as the energy source produced the heaviest body weight (Table 6.2), followed by maize, barley and wheat. The final body weight achieved by the peanut meal/wheat-fed birds (diet E) was only 86% of those fed diet A. Birds fed peanut meal/sorghum (diet B), peanut meal/maize (diet D) and peanut meal/barley (diet C) produced 92, 91 and 90% body weights respectively of those fed diet A. Moreover, similar trends were observed in body weight gains which were significantly (P<0.001) affected by dietary treatments.

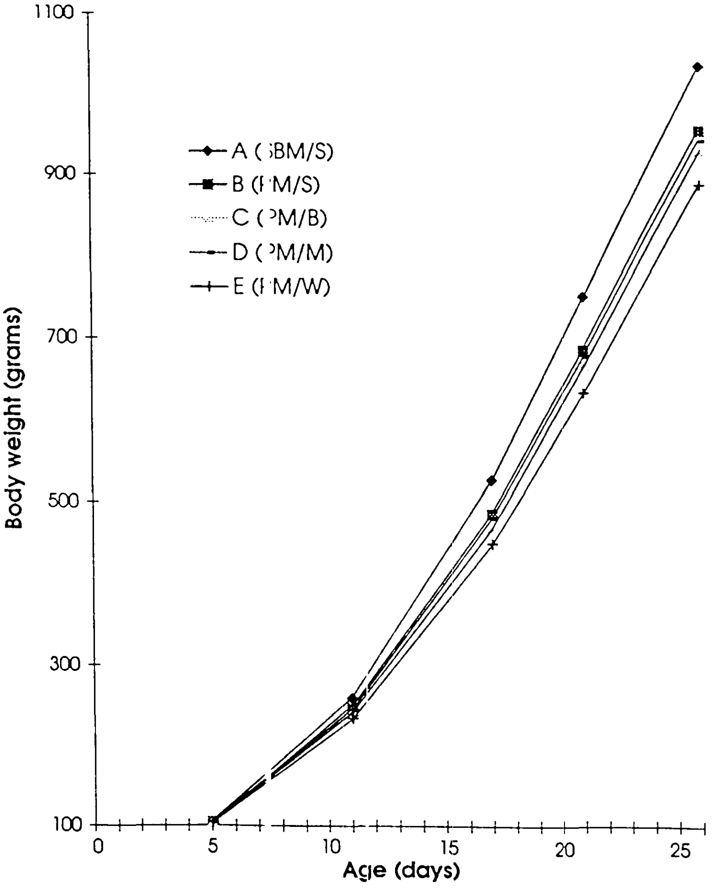

Figure 6.1. The response of body weight to the use of soybean meal (SBM)/sorghum diet, and combinations of peanut meal (PM) and different cereal grain (sorghum, barley, maize and wheat) diets.

Table 6.2. Effects of dietary treatments (soybean meal (SBM)/sorghum, peanut meal (PM)/sorghum, PM/barley, PM/maize and PM/wheat) on body weight, body weight gain, feed intake and feed conversion ratio (FCR) in broilers of 5 to 26 days of age.

Diet		A	B	C	D	E	P	LSD
		SBM/S	PM/S	PM/B	PM/M	PM/W	(%)	P = 0.05
Body weight	5 d. (g)	104	104	104	104	104	60.7 NS	0.2
	11 d. (g)	259 ^{a}	246 ^{b}	242 ^{bc}	244 ^{b}	234 ^{c}	0.05 ***	9.6
	17 d. (g)	527 ^{a}	486 ^{b}	470 ^{b}	481 ^{b}	450 ^{c}	0.00 ***	18.0
	21 d. (g)	752 ^{a}	686 ^{b}	669 ^{b}	679 ^{b}	635 ^{c}	0.00 ***	24.8
	26 d. (g)	1038 ^{a}	958 ^{b}	933 ^{b}	945 ^{b}	890 ^{c}	0.00 ***	27.7
Body weight gain 5-26 d. (g)		934 ^{a}	854 ^{b}	829 ^{b}	841 ^{b}	786 ^{c}	0.00 ***	27.7
Feed intake	5-11 d. (g)	200 ^{a}	191 ^{a}	192 ^{a}	191 ^{a}	177 ^{b}	3.51 *	13.7
	11-17 d. (g)	385 ^{a}	362 ^{b}	373 ^{ab}	374 ^{ab}	328 ^{c}	0.02 ***	22.3
	17-21 d. (g)	372 ^{a}	352 ^{ab}	374 ^{a}	360 ^{a}	323 ^{b}	2.42 *	32.7
	21-26 d. (g)	464 ^{a}	436 ^{b}	444 ^{b}	444 ^{b}	405 ^{c}	0.00 ***	17.3
	5-26 d. (g)	1421 ^{a}	1341 ^{b}	1382 ^{a}	1370 ^{ab}	1222 ^{c}	0.00 ***	62.7
FCR	5-11 d.	1.29 ^{a}	1.35 ^{b}	1.42 ^{c}	1.36 ^{b}	1.39 ^{bc}	0.04 ***	0.050
	11-17 d.	1.49 ^{a}	1.51 ^{a}	1.64 ^{b}	1.58 ^{ab}	1.52 ^{a}	3.48 *	0.105
	17-21 d.	1.67	1.76	1.88	1.82	1.75	27.1 NS	0.203
	21-26 d.	1.63	1.61	1.68	1.67	1.63	29.9 NS	0.084
	5-26 d.	1.54 ^{a}	1.57 ^{ab}	1.67 ^{c}	1.63 ^{bc}	1.56 ^{a}	0.20 **	0.066

NS = P>0.10

– = 0.05<P<0.10

Means within a row with different superscripts are significantly different (P<0.05)

Table 6.3. Effects of dietary treatments (soybean meal (SBM)/sorghum, peanut meal (PM)/sorghum, PM/barley, PM/maize and PM/wheat) on apparent metabolisable energy (AME), energy metabolisability, bulk density, digesta viscosity, excreta moisture and dry excreta weight in broilers.

Diet	**A** SBM/S	**B** PM/S	**C** PM/B	**D** PM/M	**E** PM/W	**P** (%)	**LSD** P = 0.05
AME (MJ/kg DM)	14.93^{a}	15.00^{ab}	15.16^{c}	15.13^{bc}	15.07^{abc}	3.60 *	0.156
Energy metabolisability (%)	90.3^{a}	89.3^{b}	78.4^{e}	87.5^{c}	84.8^{d}	0.00 ***	0.88
Bulk density (g/L)	645	631	560	608	681		
Digesta viscosity (cP)	1.85^{a}	1.45^{a}	9.13^{b}	1.22^{a}	11.76^{b}	0.00 ***	2.923
Excreta moisture (%)	75.0^{ab}	75.6^{a}	72.8^{c}	73.7^{bc}	74.9^{ab}	4.10 *	1.88
Dry excreta (g)	52.5^{b}	49.5^{a}	72.6^{d}	52.8^{b}	55.6^{c}	0.00 ***	2.26

NS = P>0.10

– = 0.05<P<0.10

Means within a row with different superscripts are significantly different (P<0.05)

Feed intake was also significantly (P<0.001) affected (Table 6.2). The diet A-fed birds consumed the highest amount of feed. The consumption of diets B to E was 94, 97, 96 and 86%, respectively, of that of diet A-fed birds.

Chickens fed diet A converted feed more efficiently (P<0.01) than any combinations of peanut meal with different energy source diets, followed by diets E, B and D (Table 6.2). Diet C produced the poorest FCR.

In terms of AME, the diets differed significantly (P<0.05). The use of diet A resulted in the lowest AME value (Table 6.3). The AME values for diets B to E were 0.5, 1.5, 1.3 and 0.9% higher, respectively, compared with diet A. On the other hand, the energy metabolisability of diet A was the highest (P<0.001), followed by diets B, D, E and C, which achieved 99, 97, 94 and 87% respectively of that in diet A.

The bulk density values indicate that the soybean meal and peanut meal had similar density, i.e., 645 and 631 g/L in sorghum based-diets (Table 6.3). With the changes of grain in the diets, the barley was shown to have a lower weight per unit volume than sorghum. Bulk density of the wheat was the highest of the grains (diet E).

The viscosity of the digesta (Table 6.3) showed significant (P<0.001) differences between treatments. The digesta viscosity values from diets A, B and D were quite similar: 1.85, 1.45 and 1.22 cP, respectively. However, diet C produced 9.13 cP digesta viscosity whereas the use of diet E resulted in 11.76 cP.

Excreta moisture contents (Table 6.3) were significantly (P<0.05) affected by the treatments. Diets C and D produced drier excreta outputs than diets E, A and B. The highest elimination of excreta (P<0.001) occurred in birds fed diet C. The other chickens eliminated excreta, as follows (%): 77 (diet E), 73 (diet D), 72 (diet A) and 68 (diet B) compared with diet C.

Total mortality of 9 birds (including culling) was recorded during this experiment (5, 2 and 2 birds for treatments A, C and E respectively). Two birds in treatment A and 2 birds in treatment C were euthanased because of ‘ill-thrift’, injury or leg weakness.

6.4 Discussion

Many feedstuffs will have deleterious effects when given at levels greater than optimum; they will be unpalatable, toxic, or otherwise impractical (North & Bell 1990). This experiment used levels of cereals above recommended inclusion levels (Table 6.4) to elucidate any adverse effects of these cereals when combined with peanut meal on chick performance.

Table 6.4. Normal inclusion (Sainsbury 1984) and limitation (recommended maximum inclusion level) (Evans 1985) on using sorghum, maize, wheat and barley.

	Normal inclusion		Limitation (max.)	
	Broiler minimum	Broiler maximum	Young chickens (< 4 weeks)	Meat chickens (> 4 weeks)
Sorghum	0%	50%	nl	nl
Maize	10%	40%	nl	20%
Wheat	0%	50%	nl	nl
Barley	0%	10%	15%	15%

nl = no limitation

Parsons (1993) and Dingle and Wiryawan (1994) indicated that the combined effects of limiting amino acid content, protein and amino acid digestibility, amino acid antagonists, presence of anti-nutritional factors, under- or over-processing, the physical and/or chemical properties, the presence of high levels of fibre, digesta viscosity effects and absorption rate, all result in a particular growth response of chickens.

The replacement of soybean meal with 15% peanut meal in Experiment I reduced body weight only at the earliest stage (5-12 days of age). With the use of 20% peanut meal in the present experiment, body weight and weight gain of the peanut meal/sorghum-fed birds were significantly less ($P<0.001$) than those of soybean meal/sorghum-fed birds at all stages. With a higher peanut meal inclusion, lower protein and amino acid digestibilities or availabilities in peanut meal (Table 2.10), and in particular those of three amino acids: lysine, cystine and histidine, may have resulted in amino acid deficiencies. In addition, the higher crude fibre content of peanut meal/sorghum diet compared with soybean meal/sorghum diet (4.69 and 2.42%, respectively) may interfere with amino acid digestion (Austic 1983) and increase digesta passage rate (Dingle 1992). The skin of peanut also contains tannins that increase endogenous protein outputs (Green *et al.* 1973; Rostango *et al.* 1973).

The protein digestibility of barley by rats is only about 80%, whereas that of sorghum, maize and wheat is 85-90% (Eggum 1968). Digestible amino acid coefficients are higher for the main cereals (wheat, maize, barley) than for the other grains, low tannin sorghum excepted (Rhône-Poulenc 1993). With tannins, sorghum digestibility is lowered by 10 to 20% in poultry. The actual protein content of the diets may have an effect on the growth rate of the birds as the peanut meal/barley and peanut meal/wheat diets contained less protein than the soybean meal/sorghum diet (Appendix 1).

Several cereals such as wheat and barley contain a significant amount of NSPs (Choct & Annison 1990a, b; Kopinski *et al* 1995). These carbohydrates are poorly digested by poultry because the digestive systems, including enzyme systems, of young broiler chickens do not have endogenous enzymes to digest them. Barley contains a significant amount of β-glucans that reduces nutrient assimilation, growth rate and the efficiency of feed utilisation (Classen & Campbell 1990). The NSPs decrease digestibility by increasing viscosity and thereby inhibiting both digestive and absorptive mechanisms of all nutrients in the gut (Dingle & Wiryawan 1994), and the diets used here tended to reflect the level of NSPs when bird performance was considered. However, the higher fat content in peanut meal/barley diet (10.25%) compared with peanut meal/wheat diet (6.26%), may have lifted the available energy in the barley diet, hence producing a better final body weight than that from wheat.

The use of peanut meal in sorghum-based diets depressed feed intake when the birds were very young in the previous experiment. With the 20% peanut meal usage, the chickens' consumption was significantly ($P<0.001$) reduced compared with that of soybean meal/sorghum diet-fed birds. The maximum aflatoxin content in the 20% peanut meal diet was 15 µg/kg, higher than the permitted level in the UK (Speight 1993). Moreover, the skin of peanut has a bitter taste due to tannin content, as mentioned in Chapter 4. Peanut meal may also suffer from rancidity problems because of its oil content (Shafey 1993).

The physical form and bulk density of the diet may influence palatability and affect feed consumption (Volker & Broz 1990; Mannion 1992). Bulk density values of diets A to E were 645, 631, 560, 608 and 681 g/L, respectively. The combination of soybean (Diet A) or peanut meal (Diet B) in sorghum-based diets had comparable bulk density values. The peanut meal/wheat diet (Diet E) was consumed less, possibly because of its higher nutrient density, or more likely, the higher viscosity produced by the diet reduced digesta rate of passage and hence feed intake (Classen & Campbell 1990). Iskandar and Pym (1990) stated that the reduction of food intake with increasing dietary nutrient density indicated that birds were not eating to gastrointestinal-tract capacity.

The peanut meal/sorghum-fed chickens produced a similar FCR compared with soybean meal/sorghum-fed birds, except between 5 and 11 days of age when the peanut meal/sorghum diet-fed birds performed worse ($P<0.001$) than those on the soybean meal/sorghum diet. The birds which consumed peanut meal/sorghum diet apparently needed a longer growth period to achieve the same marketable body weight as soybean meal/sorghum-fed birds.

Maize is usually considered as an excellent energy source. Nevertheless, the peanut meal/maize diet (Diet D) resulted in the second worst FCR. However, this diet used the highest level of MBM (5.08%) which may have reduced the birds' performance. (Bartlett 1974).

The effects of cereals can be ameliorated with methods to improve the digestion: for instance, Choct (1991) noted that several treatments have been shown to be effective for improving the nutritive value of cereals, including water treatment, enzyme supplementation and dietary addition of antibiotics. Enzymes can reduce or eliminate the anti-nutritive effects of NSPs (Hesselman 1989; Choct & Annison 1990a, b; Hughes *et al.* 1995). Commercial preparations of enzymes for adding to feeds are mixtures of many polysaccharidases, produced by bacteria and fungi (Dingle 1992). Enzyme proportions vary for different cereal diets. The addition of enzyme complex to broiler feeds significantly improves the nutrient retention and ME of the diet by making the otherwise non-utilisable hemicelluloses available to animals as additional energy

(Volker & Broz 1990). Bird performance can be positively influenced as well as litter quality and incidence of breast blisters in the birds.

Enzyme use is well established for diets containing barley (Göhl *et al.* 1978; Classen & Campbell 1990; Volker & Broz 1990). Large increases in growth (up to 15%) and decreases in FCR (up to 10%) occur with enzyme-supplemented rations containing barley rather than maize, rye and wheat diets (only 1-5% increases in growth rate) (Dingle 1992).

The dietary treatments produced different ($P<0.05$) AME values. Soybean meal/sorghum diet resulted in the lowest AME, followed by any combination of peanut meal/sorghum, wheat, maize and barley diets in ascending order. In contrast, the energy metabolisability of the soybean meal/sorghum diet was the highest ($P<0.001$), compared with peanut meal/sorghum, maize, wheat and barley diets.

The total fat content of the diet apparently affected the AME value because of its high digestibility. However, at increasing levels, particularly of added fat, the ME value of the fat declines (Wiseman 1984). NSPs may also interfere with and decrease the digestion and absorption of fat (Choct & Annison 1992; Dingle 1992). The soybean meal/sorghum diet contained the least total fat (3.45%). The peanut meal diets had fat contents as follow (%): 4.22 (sorghum); 4.85 (maize); 6.26 (wheat) and 10.25 (barley). Peanut meal/wheat diet contained the second highest level of fat but the AME value was third after peanut meal/maize diet, which may indicate the lower AME of wheat (Mollah *et al.* 1983; Choct & Hughes 1996).

The comparison of AME and energy metabolisability values between Experiments I (0-15% peanut meal) and III (20% peanut meal) in sorghum-based diets shows that the increase in these values recorded in the previous experiment when peanut meal was included did not appear in the present experiment. Apparently, the negative effects of the higher increase of crude fibre content (2.06% from 15 to 20% peanut meal) may have outweighed the rise in fat content (only 0.26%) as the present crude fibre level (4.69%) was higher than the optimum level of 3% (Göhl 1981).

Peanut meal/maize and the combination of either soybean or peanut meal and sorghum diets gave normal digesta viscosity values, less than 2 cP, which indicated no significant level of NSPs was present in maize and sorghum. As a result, there seemed to be no digestion problems through digesta viscosity for the birds. As in the previous experiment, peanut meal/sorghum diet produced lower digesta viscosity value than soybean meal/sorghum diet.

Barley and wheat in combination with peanut meal diets resulted in significantly ($P<0.001$) higher digesta viscosity, as follows: 9.13 and 11.76 cP, because barley and wheat contain a high level of soluble fibre (NSPs). The potential viscosity values for energy source raw materials used in poultry production are as follow (g^{-1}.ml DM): sorghum 0.26, barley 15.18-22.31, maize 0.60 and wheat 1.64-5.16 (Carré & Melcion 1995).

In essence, soybean meal/sorghum-fed chickens produced the best performance, followed by peanut meal/sorghum- and peanut meal/maize-fed birds. The results also indicated that there was a digestion problem in the birds using peanut meal/wheat and peanut meal/barley diets. However, this increase in digesta viscosity is most likely related to the cereal content and not the peanut meal content of these diets. Peanut meal/wheat-fed birds converted feed as efficiently as those fed soybean meal/sorghum diet but had the slowest growth, which prolonged the growing period. Peanut meal/barley fed-birds had the poorest performance and produced the highest amount of excreta.

Chapter 7

Conclusions

Peanut meal and peanut shell are adequate feed ingredients for use in broiler diets if several constraints, such as mould and aflatoxin contamination and possible palatability problems, are considered. The development of peanut cultivars with genetic resistance to *A. flavus* (Buddenhagen *et al.* 1987; Pettit *et al.* 1987) will ensure that the meal is safe to use. Even though peanut meal may contain mould or a high level of aflatoxin contamination (especially in the tropical countries), the use of a fungistat or an aflatoxin binding agent allows these problems to be overcome. The cost of chemical additives should be balanced against the potential benefit of peanut meal inclusion.

Peanut meal can be recommended as a replacement, up to a level of 15%, for soybean meal in a diet containing an animal protein source. The 20% peanut meal diet produced poor results in terms of growth and feed intake of the birds, although the feed conversion was similar to that of soybean. The use of more than 15% peanut meal may need supplementation with synthetic amino acids (lysine and methionine), to offset poor amino acid availability in this protein source.

From the experiment reported in Chapter 5, it can be concluded that peanut shell can be incorporated at a level of at least 9% in a diet. It should be noted that toxic residues from insecticides, fertilisers and fungal growth, although not measured, may be present.

High levels (more than 60%) of different energy source raw materials in experimental diets may affect the usefulness of high quality protein meals because of anti-nutritive factors (NSPs) which occur in cereals, such as wheat and barley. Enzyme supplementation, however, may reduce or eliminate the deleterious effects of NSPs (Choct & Annison 1990a, b; Hughes *et al.* 1995).

Although there was a large increase in the total volume of excreta by addition of peanut shell and the use of peanut meal/barley diets, the moisture content of the droppings was reduced.

In these experiments, mortality was not seemingly related to diet, although no post-mortem studies were performed. Peters and Yule (1974) observed an increase in mortality due to glucosinolates in rapeseed meal; however, peanut meal does not contain anti-nutritional factors and the peanut meal used was guaranteed to contain very little, if any, aflatoxin. The use of 9% peanut shell and the presence of NSPs in different cereal grains in the diets did not increase mortality.

It can be concluded from the work reported here that the use of peanut meal and peanut shell in Indonesian broiler chicken starter diets can lead to a reduction in feed price and provide adequate alternative feed sources for broiler production that do not suffer in terms of availability because of human demand.