ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 9 (6): 567-573, 2010
ISSN 1682-8356

Evaluation of Faba Beans, White Lupins and Peas as Protein Sources in Broiler Diets

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Abstract: The aim of the present study was to evaluate the effect of the inclusion of faba beans (*Vicia faba*), white lupins (*Lupinus albus*) and peas (*Pisum sativum*) in two different basal diets on the performance, digestive tract development and carcass characteristics of broilers housed in floor pens over a 35 d grow-out period. The experimental design was a 2 x 4 factorial arrangement of treatments which evaluated two basal wheat-soy diets (with or without meat meal) and legume grains (no legume grain, or faba beans, white lupins and peas at 200 g/kg inclusion). All diets were formulated to contain similar levels of metabolizable energy and digestible amino acids. A 3-phase feeding programme (starter, grower and finisher) was employed. The starter, grower and finisher diets were offered from day 1-7, 8-21 and 22-35, respectively. During the starter period, legume x meat meal interaction was significant ($p<0.05$) for weight gain and feed intake. Birds fed faba bean and white lupin diets containing meat meal had higher ($p<0.05$) weight gain and feed intake than those without meat meal. During day 1-21, an interaction ($p<0.05$) between legumes and meat meal was observed for weight gain, with the gain of birds fed the pea diet without meat meal being higher ($p<0.05$) that than those fed pea diet with meat meal. Over the 35 d trial period, however, with the exception of feed intake, legumes had no effect ($p>0.05$) on the performance and carcass recovery of broilers and the litter score. Weight gain and feed per gain of birds fed diets without meat meal were better ($p<0.05$) than those with meat meal. The main effect of legumes was significant ($p<0.01$ to 0.05) for the relative weight of liver and gizzard and the relative digesta weight of the crop and proventriculus. Birds fed meat meal diets had lower ($p<0.05$) relative weights of liver, pancreas and small intestine and relative digesta weight of small intestine than those fed diets with no meat meal diets. It was concluded that, when balanced for metabolizable energy and digestible amino acids, dietary inclusion of faba beans, white lupins and peas at 200 g/kg either in wheat-soybean meal or wheat-soybean meal-meat meal basal diets could support a good performance of birds over the 35-day grow-out period.

Key words: Broilers, performance, digestive tract development, faba beans, white lupins, peas

INTRODUCTION

Commercial poultry feed industry is dependent primarily on two conventional protein sources, namely, soybean meal and meat and bone meal, for practical diet formulations. In most countries, soybean meal is imported, which is a drain on foreign exchange reserves and results in high production cost. The recent ban on the use of ingredients of animal origin in poultry diets in some regions makes the situation even more critical. Therefore, evaluation of alternative protein ingredients, which are locally available and economical, is urgently required. Of the various possibilities (Ravindran and Blair, 1992), grain legumes offer the greatest promise.

The interest of using grain legumes such as faba beans (*Vicia faba*), lupins (*Lupinus* spp.) and peas (*Pisum sativum*) as alternatives to conventional protein sources has been increasing (Petterson *et al.*, 1997; Ravindran *et al.*, 2002a; Hickling 2003; Brand *et al.*, 2004; Crepon, 2006; Palander *et al.*, 2006; Nalle *et al.*, 2010a, b). These legume seeds not only offer a valuable source of protein, but also of energy due to their starch (in faba beans and peas) and fat (in lupins) contents (Petterson *et al.*, 1997; Hickling 2003). However, legume seeds also contain variable amounts of anti-nutritional factors such as Non-Starch Polysaccharides (NSP), tannins and protease inhibitors which can adversely affect nutrient utilization and animal performance (Gatel, 1994; Castell *et al.*, 1996). Thus, it is important to know how much of these ingredients can be included in practical broiler diets whilst maintaining performance. The aim of the present study was to examine the effect of feeding diets formulated to contain 200 g/kg faba beans, white lupins (*Lupinus albus*) and peas on the performance, digestive tract traits and carcass characteristics of broilers

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housed in floor pens over a 35 day grow-out period. The inclusion level of 200 g/kg was chosen on the basis of available published data (Crepon, 2006). The legumes were incorporated either in a wheat-soybean meal or a wheat-soybean meal-meat meal diet.

MATERIALS AND METHODS

The experimental procedures were approved by the Massey University Animal Ethics Committee and, complied with the New Zealand Code of Practice for the Care and Use of Animals for Scientific Purposes.

Birds and housing: A total of 1440 day-old male broilers (Ross 308), obtained from a commercial hatchery, were assigned on the basis of body weight to the 48 floor pens (30 birds/pen) on a litter of wood shavings in an environmentally controlled room. The temperature was maintained at 31°C during the first week and then it was gradually reduced to 22°C at 35 days of age. The birds received 20 h of fluorescent illumination per day and were allowed free access to the diets and water.

Diets: The study was conducted as a 2 x 4 factorial arrangement of treatments consisting of two wheat-soy basal diets (with or without meat meal) and legumes (no legume, or faba beans, white lupins and peas at 200 g/kg inclusion. Before incorporation into test diets, legume seeds with hulls were ground in a hammer mill to pass through 3 mm sieve. Other ingredients were obtained from commercial suppliers in ground form.

A total of eight diets were formulated. All diets were formulated to contain similar levels of metabolizable energy and, digestible lysine, methionine and threonine (Table 1-3), using values previously determined for these three grain legumes in our laboratory (Nalle, 2009) based on methods described by Ravindran *et al.* (2005, 2009). As per commercial practice, a xylanase product was used in all diets to eliminate the viscosity effect of soluble NSP of wheat. The diets were cold pelleted (70°C) and each of the eight dietary treatments was randomly assigned to six pens. A 3-phase feeding programme (starter, grower and finisher) was employed. The starter, grower and finisher diets were offered from day 1-7, 8-21 and 22-35, respectively.

Table 1: Composition (g/kg as is) of treatment diets for broiler starters (day 1-7)

	Wheat-soy				Wheat-soy-meat meal			
	Control	Faba bean	White lupin	Pea	Control	Faba bean	White lupin	Pea
Wheat	546	453	460	416	550	504	523	492
Soybean meal	342	281	265	312	271	168	144	179
Meat meal	-	-	-	-	100	100	100	100
Legume	-	150	150	150	-	150	150	150
Fishmeal	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Soybean oil	22.4	26.9	35.4	33.1	12.6	12.6	18.9	15.4
L-lysine	0.9	0.9	0.9	-	-	1.1	1.4	0.3
DL-methionine	2.5	3.0	2.8	2.8	2.1	2.9	2.8	2.8
L-threonine	0.3	0.7	0.1	0.2	-	0.8	0.3	0.5
Limestone	11.4	11.3	9.9	10.4	3.0	2.2	-	-
Dicalcium phosphate	15.7	15.7	17.3	16.9	4.0	1.5	3.2	2.8
Salt	0.6	0.6	0.6	1.0	0.8	0.4	0.2	0.6
Sodium bicarbonate	2.9	2.5	2.7	2.3	0.9	1.2	1.6	1.1
Trace mineral-vitamin premix[1]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Zinc bacitracin	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Xylanase[2]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Calculated analysis								
AME (MJ/kg)	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
Crude protein	265	265	265	265	284	272	269	265
Digestible lysine	13.5	13.5	13.5	14.0	13.6	13.5	13.5	13.5
Digestible methionine	3.7	3.5	3.5	3.6	4.0	3.7	3.7	3.8
Digestible met + cys	7.1	6.7	6.9	6.9	7.3	6.7	6.9	6.8
Digestible threonine	7.1	7.1	6.6	7.1	6.8	6.8	6.2	6.8
Calcium	10.0	10.0	10.0	10.0	11.4	10.6	10.3	10.1
Available phosphorus	4.8	4.8	4.8	4.8	5.2	4.8	4.8	4.8
Sodium	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Potassium	9.2	9.4	8.7	9.3	8.2	4.8	6.9	7.4
Chloride	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6

[1]Provided per kg diet: Co, 0.3 mg; Cu, 5 mg; Fe, 25 mg; I, 1 mg; Mn, 125 mg; Zn, 60 mg; choline chloride, 638 mg; trans-retinol, 3.33 mg; cholecalciferol, 60 µg; dl-α-tocopheryl acetate, 60 mg; menadione, 4 mg; thiamin, 3.0 mg; riboflavin, 12 mg; niacin, 35 mg; calcium panthothenate, 12.8 mg; pyridoxine, 10 mg; cyanocobalalamin, 0.017 mg; folic acid 5.2 mg; biotin, 0.2 mg; antioxidant, 100 mg; molybdenum, 0.5 mg; selenium, 200 µg. [2]Kemzyme, Kemin (Asia) Pte Ltd, Singapore

Table 2: Composition (g/kg as is) of treatment diets for broiler growers (day 8-21)

	Wheat-soy				Wheat-soy-meat meal			
	Control	Faba bean	White lupin	Pea	Control	Faba bean	White lupin	Pea
Wheat	611	487	496	437	684	521	545	503
Soybean meal	298	216	196	260	184	136	97.3	146
Meat meal	-	-	-	-	85.0	85.0	85.0	85.0
Legume	-	200	200	200	-	200	200	200
Tallow	35.0	35.0	35.0	35.0	13.4	26.4	35.0	34.3
Soybean oil	10.3	16.4	27.7	24.8	10.0	10.0	13.9	10.0
L-lysine	1.7	1.7	1.7	-	2.5	1.5	2.0	0.5
DL-methionine	2.2	2.9	2.6	2.6	2.2	2.6	2.5	2.6
L-threonine	0.6	1.1	0.2	0.3	0.9	1.0	0.4	0.7
Limestone	11.9	11.7	9.9	10.5	2.9	2.7	0.8	1.5
Dicalcium phosphate	19.8	19.8	22.0	21.4	7.7	7.6	9.9	9.4
Salt	1.0	1.1	1.1	1.7	0.6	1.1	0.8	1.4
Sodium bicarbonate	3.7	3.2	3.5	2.7	3.0	1.8	2.5	1.7
Trace mineral-vitamin premix[1]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Zinc bacitracin	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Xylanase[2]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Calculated analysis								
AME (MJ/kg)	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Crude protein	220	220	220	220	221	231	225	220
Digestible lysine	11.0	11.0	11.0	11.2	11.0	11.0	11.0	11.0
Digestible methionine	2.9	2.7	2.7	2.8	3.0	2.9	2.8	3.0
Digestible met + cys	6.0	5.5	5.8	5.8	6.0	5.6	5.8	5.7
Digestible threonine	6.7	6.8	6.0	6.8	6.4	6.5	5.7	6.5
Calcium	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Available phosphorus	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Sodium	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Potassium	8.1	8.4	7.4	8.4	6.4	7.3	6.2	6.6
Chloride	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6

[1]For premix composition, see Table 1. [2]Kemzyme, Kemin (Asia) Pte Ltd, Singapore

Table 3: Composition (g/kg as is) of treatment diets for broiler finishers (day 22-35)

	Wheat-soy				Wheat-soy-meat meal			
	Control	Faba bean	Lupin	Pea	Control	Faba bean	Lupin	Pea
Wheat	618	493	503	445	687	550	569	510
Soybean meal	289	207	187	249	174	102	72.8	136
Meat meal	-	-	-	-	85.0	85.0	85.0	85.0
Legume	-	200	200	200	-	200	200	200
Tallow	35.0	35.0	35.0	35	27.7	35.0	35.0	35.0
Soybean oil	15.3	21.4	32.7	29.5	5.0	6.8	17.3	14.4
L-lysine	0.7	0.7	0.7	-	1.5	1.2	1.5	-
DL-methionine	1.7	2.4	2.1	2.1	1.7	2.3	2.1	2.1
L-threonine	0.3	0.8	-	0.05	0.6	1.0	0.2	0.3
Limestone	12.4	12.2	10.4	11.0	3.3	3.1	1.3	1.9
Dicalcium phosphate	19.1	19.2	21.3	20.8	7.1	7.1	9.3	8.8
Salt	2.3	2.4	2.3	2.6	1.9	2.1	1.9	2.3
Sodium bicarbonate	1.5	0.9	1.3	0.9	0.7	0.01	0.5	-
Trace mineral-vitamin premix[1]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Zinc bacitracin	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Xylanase[2]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Calculated analysis								
AME (MJ/kg)	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
Crude protein	215	215	215	215	215	218	215	215
Digestible lysine	10.0	10.0	10.0	10.9	10.0	10.0	10.0	10.4
Digestible methionine	3.1	2.9	2.8	3.0	2.9	2.8	2.7	2.9
Digestible met + cys	6.3	5.8	6.0	6.0	5.8	5.4	5.6	5.6
Digestible threonine	6.7	6.8	6.1	6.7	6.0	6.1	5.3	6.1
Calcium	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Available phosphorus	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Sodium	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Potassium	8.0	8.3	7.3	8.1	6.2	6.7	5.6	6.5
Chloride	2.1	2.1	2.1	2.0	2.1	2.1	2.1	2.0

[1]For premix composition, see Table 1. [2]Kemzyme, Kemin (Asia) Pte Ltd, Singapore

Measurements: Body weights and feed intake were recorded on a pen basis on days 7, 21 and 35. Mortality was recorded daily. Any bird that died was weighed and the weight was used to adjust feed per gain. Feed per gain was calculated by dividing total feed intake by weight gain of live plus dead birds. Litter was subjectively scored for quality on days 21 and 35 on a scale of 1 to 5 (1 = normal, dry, friable litter and 5 = representing wet and cakey litter). The scoring was done by the same individual.

On day 35, the two birds closest to the mean pen weight were selected from each replicate, weighed and sacrificed by cervical dislocation. The weight and length of segments of digestive tract, without and with digesta, and weight of digestive organs (liver, spleen and pancreas) were determined, as described by Amerah and Ravindran (2009).

On day 35, two more birds (closest to the mean pen weight) were selected, weighed and killed by cervical dislocation, followed by exsanguination. After the removal of feathers, viscera, shanks and neck, the weight of the eviscerated hot carcass was recorded. Carcass recovery was calculated by dividing the carcass weight by the live body weight.

Statistical analysis: Pen means were used to derive performance data. For digestive tract and carcass measurements, individual birds were considered as the experimental units. The data were analyzed by a two-way analysis of variance using the General Linear Model procedure of SAS (1997). Differences were considered to be significant at $p<0.05$ and significant differences between means were separated by the Fisher's Least Significant Difference Test.

RESULTS

During the starter period, the main effects of meat meal and legumes were not significant ($p>0.05$) for performance parameters (Table 4). However, a legume x meat meal interaction ($p<0.001$) was observed for the weight gain and feed intake. The weight gain and feed intake of birds fed faba bean and white lupin-based diets containing meat meal were higher ($p<0.05$) than those of faba bean- and lupin- based diets without meat meal. On the other hand, the weight gain and feed intake of birds fed the pea diet supplemented with meat meal was comparable ($p>0.05$) to that of pea diet without meat meal. The basal diet without meat meal resulted in a better ($p<0.05$) performance compared to that with meat meal. Feed per gain of birds during the starter phase was unaffected ($p>0.05$) by dietary treatments.

During 1-21 day post-hatch, the main effect of legumes was found to be significant ($p<0.001$) for weight gain, but there was an interaction ($p<0.001$) between legumes and meat meal (Table 5). Feeding birds with the pea-based diet without meat meal produced better ($p<0.05$) weight gain than those fed the pea-based diet containing meat meal. Birds fed legume diets, with the exception of white lupin, had weight gains similar

Table 4: Performance of broilers as influenced by grain legumes and meat meal inclusion, 1-7 days post-hatch[1]

Legume	Meat meal	Weight gain (g/bird)	Feed intake (g/bird)	Feed per gain (g/g)
No legume	-	185^{a}	174^{a}	0.945
	+	178^{bc}	170^{abc}	0.960
Faba bean	-	178^{bc}	166^{b}	0.935
	+	186^{a}	177^{a}	0.949
White lupin	-	174^{b}	165^{b}	0.948
	+	181^{ac}	172^{ac}	0.953
Pea	-	183^{ac}	172^{ac}	0.941
	+	177^{bc}	168^{bc}	0.948
SEM[2]		2.38	2.10	0.007
Main effects				
Legume				
No legume		182	173	0.953
Faba bean		182	171	0.942
White lupin		178	169	0.951
Pea		181	170	0.944
Meat meal				
-		180	169	0.942
+		181	172	0.952
Probabilities, p<				
Legume		NS	NS	NS
Meat meal		NS	NS	NS
Legume x Meat meal		***	***	NS

^{a,b,c}Means in a column with different superscripts differ ($p<0.05$). NS = Not Significant; *** = $p<0.001$. [1]Each value represents the mean of six replicates (30 birds/replicate). [2]Pooled standard error of mean

Table 5: Performance of broilers as influenced by grain legumes and meat meal inclusion, 1-21 days post-hatch[1]

Legumes	Meat meal	Weight gain (g/bird)	Feed intake (g/bird)	Feed per gain (g/g)	Litter score
No legume	-	1095^{b}	1443	1.322	1.58
	+	1094^{b}	1450	1.328	1.42
Faba bean	-	1100^{bc}	1430	1.304	1.75
	+	1133^{ac}	1478	1.311	1.50
White lupin	-	1150^{a}	1469	1.291	1.25
	+	1155^{a}	1506	1.315	1.25
Pea	-	1131^{a}	1464	1.296	1.58
	+	1091^{b}	1456	1.338	1.33
SEM[2]		11.6	17.4	0.010	0.113
Main effects					
Legume					
No legume		1094^{b}	1447	1.325	1.50^{a}
Faba bean		1117^{b}	1455	1.317	1.62^{a}
White lupin		1153^{a}	1488	1.302	1.25^{b}
Pea		1111^{b}	1460	1.317	1.46^{ab}
Meat meal					
-		1119	1452	1.303^{b}	1.54
+		1118	1473	1.323^{a}	1.42
Probabilities, p<					
Legume		***	NS	NS	**
Meat meal		NS	NS	*	NS
Legume x Meat meal		*	NS	NS	NS

^{a,b,c}Means in a column with different superscripts differ ($p<0.05$). NS = Not Significant; ** = $p<0.01$; * = $p<0.05$. [1]Each value represents the mean of six replicates (30 birds/replicate). [2]Pooled standard error of mean (p>0.05) to those fed diets without legumes. Inclusion of meat meal had no effect (p>0.05) on the weight gain and feed intake, but influenced (p<0.05) the feed per gain. Diets without meat meal produced lower (p<0.05) feed per gain than those with meat meal. The litter score of birds fed white lupin diet was lower (p<0.05) than those fed diets with no legume diet and faba bean, but comparable (p>0.05) to those fed the pea diets. Meat meal had no effect (p>0.05) on the litter score. Legume x meat meal interaction was not significant (p>0.05) for the litter scores.

Over the 35-day trial period, legumes had no effect (p>0.05) on the weight gain and feed per gain of broilers (Table 6). The feed intake of birds fed the white lupin diet was higher (p<0.05) than those fed diets with no legumes, faba beans and peas. Weight gain and feed per gain of birds fed diets without meat meal were better (p<0.05) than those broilers fed diets with no meat meal. Dietary treatments had no effect (p>0.05) on the litter score or carcass recovery. Legume x meat meal interaction was not significant (p>0.05) for any performance traits, litter score and on carcass recovery.

The effects of dietary treatments on the gross morphology of the digestive tract of broilers are presented in Table 7. In general, it was found that the dietary treatments had no effects on the majority of gross morphology parameters. The main effects of legumes were found to be significant (p<0.01 to 0.05) for the relative weights of liver and gizzard and the relative digesta weight of the crop and proventriculus. The liver weight of birds fed legume diets (except pea diets) had higher relative empty weight of gizzard than those fed the control diet containing no legume. The main effect of meat meal was observed to be significant (p<0.01 to 0.05) for the relative weights of liver, pancreas and small intestine and the relative digesta weight of the small intestine. Overall, birds fed meat meal diets had lower (p<0.05) relative weights of liver, pancreas and small intestine and relative digesta weight of small intestine than those fed diets with no meat meal. Legume x meat meal interaction was not significant (p>0.05) for digestive tract traits, except for the relative digesta weight of crop. Digesta weight in the crop of birds fed faba bean diets containing meat meal was higher (p<0.05) than those fed faba bean diets without meat meal.

DISCUSSION

The finding that diets containing 200 g/kg of grain legumes can be included in broiler diets with no adverse effects on the weight gain and feed efficiency is in agreement with published data (Olver and Jonker, 1997; Farrell *et al.*, 1999; Crepon, 2006; Nalle *et al.*, 2010a). However, deleterious effects due to the inclusion of peas at a level of 200 g/kg in broiler diets were also observed in some studies (McNeill *et al.*, 2004), which may be attributed primarily to cultivar differences or failure to consider digestibility differences in feed formulations. The level of anti-nutritional factors in peas is known to vary depending on the cultivar and growing season (Gatel, 1994; Castell *et al.*, 1996).

During the starter period, the weight gain of broilers fed the wheat-soy diet containing faba beans and white lupins was significantly lower than those fed wheat-soy-

Table 6: Performance of broilers as influenced by grain legumes and meat meal inclusion, 1-35 days post-hatch[1]

Legumes	Meat meal	Weight gain (g)	Feed intake (g)	Feed per gain (g/g)	Litter score	Carcass recovery (%)[2]
No legume	-	2459	3718	1.516	1.25	72.1
	+	2438	3738	1.538	1.67	73.3
Faba beans	-	2500	3687	1.497	1.83	72.5
	+	2431	3709	1.542	1.58	72.0
White lupins	-	2576	3861	1.523	1.50	71.9
	+	2495	3803	1.560	1.75	71.7
Peas	-	2548	3772	1.491	1.33	72.6
	+	2369	3694	1.582	1.33	73.0
SEM[3]		39.0	39.3	0.028	0.148	0.332
Main effects						
Legume						
No legume		2449	3728[b]	1.527	1.46	72.6
Faba beans		2466	3698[b]	1.520	1.71	72.2
White lupins		2536	3832[a]	1.542	1.62	71.8
Peas		2458	3733[b]	1.537	1.33	72.8
Meat meal						
-		2521[a]	3760	1.507[b]	1.48	72.2
+		2433[b]	3736	1.555[a]	1.58	72.5
Probabilities, p<						
Legume		NS	*	NS	NS	NS
Meat meal		**	NS	*	NS	NS
Legume x Meat meal		NS	NS	NS	NS	NS

[a,b,c]Means in a column with different superscripts differ (p<0.05). NS = Not Significant; ** = p<0.01; * = p<0.05. [1]Each value represents the mean of six replicates (30 birds/replicate). [2]Each value represents the mean of 12 birds. [3]Pooled standard error of mean

Table 7: Influence of grain legumes and meat meal on the digestive tract size of broilers (determined on day 35)[1]

	Legume									Main effects								
										Legume						Probability, P <		
	No legume		Faba bean		White lupin		Pea							MM				
	-MM2	+MM	-MM	+MM	-MM	+MM	-MM	+MM	Pooled SEM[4]	No leg.	Faba bean	White lupin	Pea	-	+	Leg.	MM	MM x Leg.
Relative organ weight (g/kg BW)																		
Heart	4.30	3.85	4.02	4.17	4.10	3.95	4.04	3.90	0.12	4.07	4.09	4.02	3.97	4.11	3.97	NS	NS	NS
Liver	19.9	18.3	18.7	18.9	21.3	20.4	20.8	18.6	0.60	19.1^{b}	18.8^{b}	20.8^{a}	19.7^{ab}	20.1^{a}	19.0^{b}	**	*	NS
Spleen	1.01	0.869	0.809	0.806	0.954	0.938	0.936	0.879	0.06	0.938	0.816	0.946	0.907	0.931	0.873	NS	NS	NS
Pancreas	1.46	1.25	1.47	1.44	1.40	1.31	1.41	1.33	0.05	1.37	1.43	1.35	1.35	1.44^{a}	1.31^{b}	NS	**	NS
Relative empty organ weight (g/kg BW)																		
Crop	1.93	1.80	2.01	2.00	2.04	2.11	1.87	1.74	0.10	1.87	2.00	2.07	1.87	1.96	1.95	NS	NS	NS
Proventriculus	2.01	1.90	1.94	1.91	1.90	1.93	2.02	1.67	0.10	1.96	1.92	1.91	1.88	1.94	1.89	NS	NS	NS
Gizzard	6.20	6.49	6.85	7.53	6.80	6.84	6.54	6.43	0.28	6.17^{b}	7.26^{a}	6.83^{a}	6.72^{ab}	6.57	6.93	**	NS	NS
Small Intestine[3]	13.3	12.2	13.2	12.2	13.7	12.3	12.8	11.6	0.42	12.7	12.6	13.0	12.7	13.2^{a}	12.3^{b}	NS	**	NS
Caeca	0.908	0.834	0.842	0.793	0.875	0.834	0.838	0.806	0.04	0.871	0.818	0.855	0.822	0.866	0.816	NS	NS	NS
Relative length (cm/kg BW)																		
Proventriculus	1.70	1.62	1.63	1.68	1.71	1.74	1.64	1.69	0.05	1.66	1.66	1.73	1.66	1.67	1.69	NS	NS	NS
Gizzard	1.85	1.85	1.80	1.87	1.90	1.90	1.82	1.89	0.05	1.85	1.83	1.90	1.86	1.84	1.87	NS	NS	NS
Small intestine	71.0	71.3	72.6	72.3	71.7	69.5	73.2	71.6	1.93	71.6	71.1	71.5	73.4	72.4	71.4	NS	NS	NS
Caeca	7.94	7.71	7.77	7.89	7.61	7.68	7.83	8.06	0.29	7.87	7.80	7.67	8.14	7.94	7.80	NS	NS	NS
Relative digesta content (g/kg BW)																		
Crop	4.75^{cd}	4.34^{cd}	3.73^{d}	9.83^{a}	6.85^{bc}	9.32^{ab}	4.53^{cd}	4.88^{cd}	1.33	5.50^{b}	7.55^{ab}	8.56^{a}	5.35^{b}	6.02	7.45	*	NS	**
Proventriculus	0.934	0.811	0.943	1.07	1.23	1.36	1.04	1.17	0.15	0.872^{b}	1.00^{ab}	1.30^{b}	1.02^{ab}	1.04	1.06	*	NS	NS
Gizzard	1.23	1.89	1.68	2.08	2.19	2.42	1.59	1.68	0.30	1.55	1.86	2.30	1.68	1.67	2.03	NS	NS	NS
Small Intestine	40.1	36.2	40.1	38.9	43.4	36.3	39.2	37.9	1.63	37.5	38.5	39.0	39.4	40.0^{a}	37.2^{b}	NS	**	NS
Caeca	1.85	1.76	1.89	1.98	1.67	1.88	1.65	1.48	0.19	1.81	1.76	1.77	1.66	1.78	1.72	NS	NS	NS

^{a,b,c,d}Means in a row with different superscripts differ ($p<0.05$). [1]Each value represents the mean of 12 birds. [2]MM = Meat meal.
[3]Small intestine = duodenum + jejunum + ileum. [4]SEM = Pooled standard error of mean. Leg. = Legume

meat meal diet which contained these legume seeds. No differences in weight gain, however, were observed over the 21-day and 35-day feeding periods, and this may indicate that the older birds have greater tolerance to NSP in the grain legumes than the younger birds. The lower weight gain shown by young birds fed wheat-soy-meat-meal diet containing faba beans and white lupins was caused largely by the lower feed intake in this group compared to those fed wheat-soy diet which contained these legume seeds.

Birds fed diets without meat meal gave better weight gain and feed per gain than those fed diets containing meat meal. The lower performance of birds fed diets with meat meal may be reflective of the quality of meat meal used in the present study. The wide variability in the contents and digestibility of amino acids in meat meal is known (Ravindran *et al.*, 2002b; 2005). Thus it is possible that the published digestible amino acid data used in the diet formulation may have overestimated the actual digestible amino acid values of the meat meal sample used in the present study.

The litter quality of the birds over 35-day period of the trial was not affected by the inclusion of these grain legumes. Because of the presence of NSP in grain legumes, it was anticipated that there will be a wet litter problem when these ingredients are included in broiler diets. It is possible that either the inclusion level of 200 g/kg is low to cause wet litter problems or the inclusion of exogenous xylanase may have ameliorated the viscosity effects of NSP.

In summary, the performance, digestive tract development, carcass recovery and litter scores of broilers were not affected by the inclusion of faba beans, white lupins and peas in broiler diets. The present data demonstrate that, when the diets are balanced in terms of metabolizable energy and digestible amino acids, faba beans, white lupins and peas can be included at 200 g/kg level to support good production performance of broilers. Further studies are warranted to investigate the possible use of higher levels of grain legumes in broiler feeding.

ACKNOWLEDGEMENTS

This project was partly supported by the sustainable farming fund (SFF) of the Ministry of Agriculture and Forestry, Wellington. The SSF project funding and reporting are facilitated through the Foundation of Arable Farming (FAR). The assistance of Jacqui Johnston of FAR is gratefully acknowledged.

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