doi: 10.17221/330/2014-VETMED

Effects of lupin seed supplementation on egg production performance, and qualitative egg traits in laying hens

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ABSTRACT: We investigated the effects of lupin (*Lupinus angustifolius* L.) seed supplementation on egg production performance and egg quality in laying hens. A total of 120 Hy-Line Brown laying hens (29-week old) were used in a nine week trial. Laying hens were sorted into pens with six birds per pen and five pens per treatment. Treatments were (1) control, corn-soybean meal-based control diets, (2) 11% lupin (control + 11% lupin), (3) 16.5% lupin (control + 16.5% lupin), and (4) 22% lupin (control + 22% lupin). The average daily feed intake of laying hens fed with lupin diets was increased compared with control at Week 6 ($P < 0.05$). The egg production rate was higher in lupin diets than in the control diet at Week 3, 4, and 5 ($P < 0.05$). Supplementation with lupin improved the egg production rate linearly at Week 3, 4, 5, and 9, as dietary lupin increased from 11 to 22%. Laying hens fed with 11% and 16.5% lupin diets had higher rates of extra-large-sized egg production at Week 1 (quadratic, P = 0.04). Yolk colour was higher in hens fed lupin diets than in those fed with the control at Week 9 ($P < 0.05$). Supplementation of lupin in laying hen diets linearly improved the yolk colour ($P < 0.05$) at Week 5. In conclusion, supplementation of the diet with lupin can improve egg production and yolk colour with no apparent effect on average daily feed intake and eggshell quality in laying hens.

Keywords: *Lupinus angustifolius* L.; laying performance; egg quality; yolk colour

Due to limitations connected with the use of animal proteins, plant-based protein meals have attracted considerable attention in recent years as an alternative to animal protein meal. Due to its high protein and food energy content, soybean meal is a potentially suitable plant protein meal in poultry diets (Hove 1974; Watkins and Mirosh 1987; Nalle et al. 2011). However, due to the increasing price of soybean meal, many researchers have sought alternative plant protein sources.

Grain legumes have been used as alternatives to animal proteins in poultry feed. Among the various grain legumes, lupins can be used as an alternative to soybeans and are highly regarded as a stock feed, not only for poultry but also for pigs, ruminants, and as fish-feed (Donovan et al. 1993; Glencross et al. 2004; Laudadio and Tufarelli 2011a). Lupin seeds contain similar protein content to soybeans and also harbour less fat. Moreover, lupin seeds are gluten-free, high in amino acids, dietary fibre, and antioxidants (Lampart-Szczapa et al. 2003). In a previous report, sweet lupin, at 6, 12, and 18% inclusion rates, elicited significant changes in fattening capacity, the percentage of fat, and the percentage of valuable parts in the carcasses of broilers (Schamsschargh et al. 1994). However, dietary supplementation with up to 20% of white lupin had adverse effects on performance indicators, carcass value, and meat quality, including average daily gain, protein deposition in the carcass, and energy retention in broilers (Rothmaier and Kirchgessner 1994).

To our knowledge, the effects of Australian sweet lupin on egg production performance, eggshell parameters, and egg quality have not been systematically investigated in laying hens. Thus, the aim

*These authors contributed equally to this work, share co-first authorship

Supported by the Cooperative Research Program for Agricultural Science and Technology Development (Project No. PJ011212), Rural Development Administration, Republic of Korea.

doi: 10.17221/330/2014-VETMED

of the present study was to evaluate the effects of lupin supplementation on egg production performance, eggshell parameters, and egg quality in laying hens.

MATERIAL AND METHODS

The Animal Care and Use Committee of Dankook University approved all experimental protocols used in the current study.

Table 1. Basal diet composition (as-fed basis)

Item	Control	Lupin (%)		
		11	16.5	22
Ingredients (%)				
Corn	48.71	57.15	56.04	54.48
Soybean meal, 45% CP	25.08	17.50	13.30	9.24
Lupin, 31% CP	–	11.00	16.50	22.00
Wheat	11.00	–	–	–
Limestone	9.70	9.71	9.73	9.75
Animal fat	3.10	2.10	1.80	1.90
Monocalcium phosphate	1.59	1.61	1.60	1.58
Salt	0.35	0.35	0.35	0.35
Methionine	0.17	0.19	0.20	0.21
Choline	0.10	0.10	0.10	0.10
Mineral[1]	0.10	0.10	0.10	0.10
Vitamin[2]	0.06	0.06	0.06	0.06
Lysine	0.04	0.13	0.22	0.23
Chemical composition[3]				
ME (MJ/kg)	11.94	11.86	11.76	11.77
Crude protein	16.89	16.95	16.88	16.93
Crude fat	5.15	4.88	4.81	4.78
Crude fibre	2.22	2.14	2.09	2.06
Crude ash	14.28	14.08	13.95	13.86
Ca	4.08	4.08	4.09	4.07
P	0.41	0.40	0.38	0.37
Lysine	0.72	0.73	0.71	0.70
Methionine	0.41	0.40	0.39	0.38

[1]Provided per kg of complete diet: Cu – 25 000 mg, Fe – 40 000 mg, Zn – 60 000 mg, Mn – 80 000 mg, I – 1500 mg, Co – 300 mg, Se – 150 mg

[2]Provided per kg of complete diet: vitamin A – 12 500 000 IU, vitamin D3 – 2 500 000 IU, vitamin E – 10 000 IU, vitamin K3 – 2000 mg, biotin – 50 mg, folic acid – 500 mg, niacin – 35 000 mg, Ca pantothenate – 10 000 mg, vitamin B6 – 1000 mg, vitamin B2 – 5000 mg, vitamin B1 – 1000 mg, and vitamin B12 – 15 mg

[3]Analysed values

Experimental design, animals and diets. A total of 120 Hy-Line Brown laying hens (29-week old) were used in a nine week trial. Laying hens were sorted into pens with six birds per pens and five pens per treatments. Treatments were (1) control, corn-soybean meal-based control diets, (2) 11% lupin (control + 11% lupin), (3) 16.5% lupin (control + 16.5% lupin), and (4) 22% lupin (control + 22% lupin). All the diets were formulated to meet or exceed the NRC (1994) nutritional requirements (Table 1). The nutrient composition of lupin seed is shown in Table 2. Dietary calcium (Ca), phosphorus (P), and crude protein (CP) were analysed according to the procedures described by the AOAC (2012). Dietary Ca was assayed using atomic absorption spectrophotometry after wet ash procedures and P was determined using colorimetry. Amino acid contents were measured using an amino acid analyser (Beckman 6300, Beckman Coulter, Inc., Fullerton, USA) after 24 h 6 N HCl hydrolysis at 110 °C (AOAC 2012). Energy was determined by using a Parr 6100 oxygen bomb calorimeter (Parr instrument Co., Moline, USA). Laying hens were raised in a temperature-controlled house, maintained at 21 °C with a light regime of 16-h light/8-h darkness. Laying hens were reared in adjacent steel cages, equipped with a nipple drinker, trough, and egg collecting plate. Birds had *ad libitum* access to water and feed.

Sampling and measurements. Daily records of egg production and feed intake were kept throughout the experimental period. Egg production is expressed as an average production of hen per day, calculated from the total number of eggs divided by the experimental time (unit: days), and summarised on an average basis. The average daily feed intake was calculated on a weekly basis during the trial

Table 2. Nutrient composition of lupin (%)

Moisture	9.74
Crude protein	31.07
Ether extract	5.48
Nitrogen free extract	37.75
Crude fibre	14.95
Ash	2.54
Ca	0.20
P	0.30
Lysine	2.02
Methionine	0.24
Threonine	1.04
Cysteine	0.39

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Table 3. The effects of lupin supplementation on feed intake (g) in laying hens

Week	Control	Lupin (%)			SEM	P-value		
		11	16.5	22		control vs lupins[1]	linear[2]	quadratic
1	109.8	110.8	112.2	111.6	1.5	0.36	0.32	0.70
2	109.2	111.2	111.4	112.0	2.7	0.46	0.45	0.84
3	111.2	112.8	109.8	110.6	2.3	0.98	0.71	0.87
4	111.0	112.6	112.4	113.4	1.3	0.23	0.25	0.75
5	110.8	113.8	114.2	112.4	2.0	0.29	0.59	0.27
6	109.8	114.0	115.2	112.8	1.7	0.04	0.17	0.06
7	111.6	113.6	116.0	113.4	2.1	0.30	0.45	0.28
8	111.0	113.2	114.6	114.0	1.4	0.12	0.15	0.36
9	112.0	114.7	113.0	112.0	1.7	0.66	0.79	0.42
1–9	110.7	113.0	113.2	112.5	1.8	0.27	0.34	0.64

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

period. In total, 20 saleable eggs (no shell defects, cracks, or double yolks) were collected randomly from each treatment on a weekly basis and used to determine the egg shell parameters and quality. Egg weight was measured using an egg multi tester (Touhoku Rtythm Co. Ltd., Tokyo, Japan), and extra large-sized eggs (60–68 g) were recorded. The total average egg weight was calculated based on weekly egg weight measurements. Eggshell colour was determined using a colour fan (Eggshell colour fan, Samyang Feed Co., Korea) with a range from 1 to 15. A dial gauge (Ozaki Mfg. Co. Ltd., Tokyo, Japan) was used to measure egg shell thickness, which was determined based on the average thickness of the rounded end, pointed end, and the middle of the egg, excluding the inner membrane. Egg yolk colour and Haugh units were evaluated using an egg multi-tester (Touhoku Rtythm Co. Ltd., Tokyo, Japan). These eggs were immersed in a series of chloride solutions (0.010 increments between 1.060 and 1.110) to determine specific gravity (Yan et al. 2011).

Statistical analysis. All data were subjected to statistical analyses as a randomised complete block design using the GLM procedure of the SAS software (SAS Institute 1996), with the pen as the experimental unit. Orthogonal contrasts used to separate treatment means were control vs lupins (11, 16.5, and 22%). The means were separated us-

Table 4. The effects of lupin supplementation on egg production (%) in laying hens

Week	Control	Lupin (%)			SEM	P-value		
		11	16.5	22		control vs lupins[1]	linear[2]	quadratic
1	93.2	93.8	94.4	94.0	0.9	0.50	0.60	0.58
2	94.2	95.0	94.6	94.6	0.7	0.48	0.81	0.53
3	93.2	96.2	97.0	97.4	1.1	0.02	0.02	0.33
4	93.0	95.0	96.4	96.8	0.9	0.01	0.01	0.41
5	94.2	94.8	96.6	96.2	0.6	0.03	0.01	0.37
6	95.2	96.0	96.8	97.6	0.8	0.14	0.06	0.97
7	96.6	96.4	97.0	98.0	0.6	0.62	0.15	0.29
8	94.2	94.8	96.0	95.4	0.6	0.09	0.08	0.28
9	93.0	94.6	95.4	96.0	1.1	0.07	0.05	0.70
1–9	94.1	95.2	96.0	96.2	0.9	0.35	0.18	0.45

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

doi: 10.17221/330/2014-VETMED

Table 5. The effects of lupin supplementation on broken egg rate (%) in laying hens

Week	Control	Lupin (%)			SEM	*P*-value		
		11	16.5	22		control vs lupins[1]	linear[2]	quadratic
1	5.2	3.8	5.1	3.1	0.6	0.07	0.05	0.57
2	4.7	3.8	4.0	3.3	0.6	0.20	0.20	0.86
3	4.3	4.2	3.9	3.6	0.5	0.52	0.33	0.84
4	3.9	3.7	3.6	3.6	0.4	0.71	0.69	0.89
5	4.7	4.2	4.3	4.0	0.5	0.39	0.38	0.89
6	3.8	3.3	3.7	3.3	0.4	0.49	0.59	0.90
7	4.2	3.8	3.6	3.3	0.9	0.57	0.51	0.98
8	5.6	5.0	3.7	4.4	0.6	0.10	0.08	0.32
9	4.4	3.8	3.8	3.3	0.9	0.46	0.42	0.95
1–9	4.5	4.0	4.0	3.5	0.5	0.28	0.45	0.78

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

ing orthogonal polynomial contrasts to examine the effects of lupin diets. Variability in the data was expressed as the pooled standard error of the mean (SEM). *P*-values < 0.05 were considered to indicate statistical significance.

RESULTS

Egg production performance

Laying hens fed with lupin diets had higher average daily feed intake ($P = 0.04$) than laying hens fed the control diet at six weeks (Table 3). Laying hens fed with lupin-supplemented diets had higher egg production rates than laying hens fed the control diet at three weeks ($P = 0.02$), four weeks ($P = 0.01$), and five weeks ($P = 0.03$). Further, laying hens fed with lupin-supplemented diets exhibited linearly improved egg production at three weeks ($P = 0.02$), four weeks ($P = 0.01$), five weeks ($P = 0.01$), and nine weeks ($P = 0.05$; Table 4). During the experimental period, no difference ($P > 0.05$) was observed in broken egg production among the treatments (Table 5). After one week, the diets supplemented with 11% and 16.5% lupin had a higher ratio (quadratic, $P = 0.04$) of extra-large-sized eggs than those fed with the 22% lupin diet (Table 6).

Table 6. The effects of lupin supplementation on the ratio of extra large-sized eggs (%) in laying hens

Week	Control	Lupin (%)			SEM	*P*-value		
		11	16.5	22		control vs lupins[1]	linear[2]	quadratic
1	54.2	59.4	59.4	55.0	2.2	0.16	0.81	0.04
2	52.4	59.7	56.7	58.7	2.6	0.06	0.19	0.31
3	54.2	57.3	55.8	55.9	3.3	0.59	0.82	0.65
4	55.6	59.4	57.8	58.1	4.4	0.58	0.77	0.69
5	52.8	59.0	58.3	56.9	3.8	0.25	0.50	0.33
6	54.5	56.3	59.2	56.7	3.1	0.44	0.51	0.50
7	54.5	60.0	59.7	58.9	2.3	0.08	0.23	0.19
8	57.6	60.1	59.7	57.0	1.9	0.57	0.78	0.19
9	56.3	59.4	57.2	55.6	3.4	0.78	0.78	0.50
1–9	54.7	59.0	58.2	57.0	2.8	0.25	0.67	0.48

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

doi: 10.17221/330/2014-VETMED

Egg quality

No differences were observed in colour, strength, or thickness of the eggshell (Table 7) or specific gravity or weight (Table 8) of the egg during the experimental period ($P > 0.05$).

Laying hens fed with lupin-supplemented diets had higher yolk colour ($P = 0.02$) than laying hens fed the control diet at nine weeks. Also, laying hens fed with lupin-supplemented diets exhibited linearly improved yolk colour at five weeks ($P = 0.05$). No differences were observed in yolk height or Haugh units during the experimental period ($P > 0.05$; Table 9).

DISCUSSION

Soybean meal, as an alternative to animal protein meal in poultry diets, has a high-protein content, a

Table 7. The effects of lupin supplementation on eggshell colour, strength (kg/cm^2) and thickness (mm^{-2}) in laying hens

	Week	Control	Lupin (%)			SEM	*P*-value		
			11	16.5	22		control vs lupins[1]	linear[2]	quadratic
Egshell colour	1	11.3	11.3	11.0	11.0	0.3	0.57	0.40	0.93
	2	11.7	11.7	11.5	11.6	0.5	0.78	0.75	0.87
	3	11.8	11.7	11.9	11.8	0.5	1.00	0.93	1.00
	4	11.4	12.0	11.9	11.8	0.4	0.23	0.53	0.31
	5	11.7	12.0	11.8	12.0	0.3	0.43	0.54	0.78
	6	11.9	12.1	12.2	12.3	0.2	0.30	0.22	0.90
	7	12.1	12.0	12.1	12.2	0.3	0.92	0.65	0.73
	8	12.1	12.1	12.1	12.2	0.3	0.82	0.72	0.84
	9	11.9	12.0	11.8	11.8	0.2	0.90	0.63	0.83
	1–9	11.8	11.9	11.8	11.9	0.3	0.66	0.45	0.87
Egshell strength	1	3.372	3.414	3.373	3.394	0.120	0.88	0.96	0.93
	2	3.473	3.515	3.529	3.597	0.120	0.59	0.47	0.91
	3	3.561	3.592	3.603	3.583	0.120	0.82	0.89	0.83
	4	3.597	3.687	3.642	3.620	0.131	0.73	0.96	0.67
	5	3.694	3.714	3.740	3.681	0.116	0.89	0.98	0.73
	6	3.574	3.503	3.563	3.521	0.108	0.72	0.84	0.89
	7	3.701	3.669	3.634	3.524	0.146	0.57	0.38	0.80
	8	3.515	3.485	3.564	3.620	0.134	0.79	0.51	0.75
	9	3.494	3.653	3.634	3.643	0.138	0.35	0.49	0.59
	1–9	3.553	3.581	3.587	3.576	0.125	0.70	0.78	0.82
Egshell thickness	1	39.24	39.04	39.21	39.07	0.55	0.61	0.88	0.57
	2	39.44	39.24	39.41	39.27	0.54	0.72	0.99	0.62
	3	39.74	39.54	39.71	39.57	0.50	0.42	0.61	0.71
	4	39.84	39.64	39.81	39.67	0.56	0.99	0.84	0.92
	5	39.94	39.74	39.91	39.77	0.51	0.73	0.87	0.51
	6	40.41	40.13	40.39	40.52	0.41	0.89	0.75	0.60
	7	40.09	39.61	39.75	40.19	0.41	0.60	0.81	0.25
	8	39.92	39.68	39.63	40.17	0.29	0.78	0.58	0.18
	9	39.72	39.82	40.12	40.18	0.28	0.33	0.18	0.98
	1–9	39.82	39.60	39.77	39.82	0.45	0.64	0.72	0.56

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

doi: 10.17221/330/2014-VETMED

Table 8. The effects of lupin supplementation on egg gravity and egg weight in laying hens

	Week	Control	Lupin (%)			SEM	*P*-value		
			11	16.5	22		control vs lupins[1]	linear[2]	quadratic
Egg gravity	1	1.091	1.089	1.089	1.088	0.002	0.19	0.19	0.75
	2	1.091	1.094	1.091	1.092	0.002	0.61	0.89	0.55
	3	1.095	1.093	1.094	1.092	0.002	0.19	0.14	0.86
	4	1.092	1.094	1.094	1.094	0.001	0.17	0.22	0.59
	5	1.095	1.094	1.095	1.096	0.001	0.82	0.72	0.43
	6	1.095	1.094	1.094	1.096	0.001	0.66	0.73	0.25
	7	1.095	1.094	1.095	1.096	0.001	0.82	0.47	0.23
	8	1.094	1.095	1.095	1.095	0.001	0.50	0.61	0.70
	9	1.095	1.095	1.095	1.095	0.001	0.92	0.94	0.86
	1–9	1.095	1.094	1.094	1.094	0.001	0.54	0.57	0.62
Egg weight	1	60.7	59.6	60.5	59.1	1.2	0.47	0.47	0.94
	2	59.6	60.4	60.0	59.8	1.3	0.74	0.94	0.70
	3	59.6	59.9	60.1	59.7	1.2	0.80	0.89	0.77
	4	59.8	59.9	60.4	60.1	0.9	0.78	0.75	0.85
	5	59.8	59.9	60.4	60.1	0.9	0.78	0.75	0.85
	6	60.1	59.1	60.3	60.2	0.7	0.81	0.62	0.54
	7	59.7	60.5	60.1	59.4	0.6	0.72	0.55	0.20
	8	59.8	60.4	60.1	60.0	0.6	0.57	0.94	0.49
	9	59.8	60.2	60.2	59.6	0.6	0.76	0.77	0.38
	1–9	59.9	60.0	60.3	59.8	0.9	0.75	0.71	0.64

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

balanced amino acid profile, and represents an adequate source of essential fatty acids (Hammershoj and Steenfeldt 2005). However, increasing demand for soybean meal, associated with the increase in poultry production worldwide, has resulted in increased prices (Laudadio and Tufarelli 2010). Due to low protein content, amino acid imbalances, and the presence of anti-nutritional factors, few plant protein sources are suitable as replacements for soybean meal in poultry diets (Rubio et al. 2003). Lupins have attracted considerable attention for poultry diets, due to their high levels of protein and unsaturated fatty acids, favourable price, and market availability (Ravindran and Blair 1992; Martinez-Villaluenga et al. 2006; Boschin et al. 2008; Vicenti et al. 2009). In the present study, we evaluated the effects of lupin diets in replacing soybean meal on egg production and egg quality in laying hens. It is well documented that lupin diets, as an alternative to soybean meal, have positive effects on performance, carcass value, and meat quality in broilers (Suchy et al. 2010; Laudadio and Tufarelli 2011b). Diets with different concentrations of lupin seeds influenced the average daily feed intake in the present study. Unlike our results, Rubio et al. (2003) reported that the body weight and average daily feed intake of chickens fed diets containing whole lupin seed meal (400 g/kg) were lower than controls. Also, lupin-supplemented laying hen diets reduced feed consumption and weight gain, but increased feed-to-gain ratio (Viveros et al. 2007).

In the present study, lupin-fed laying hens had higher egg production rates than those receiving the control diet. Also, laying hens fed with 11% and 16.5% lupin diets had higher ratios of extra-large-sized eggs than the control and hens fed the 22% lupin diet. The effects of lupin diets on egg production performance in laying hens that we observed are inconsistent with some previous studies. In a previous report, 25% lupin supplementation in layer diets resulted in higher performance in a 40-

doi: 10.17221/330/2014-VETMED

Table 9. The effects of lupin supplementation on yolk colour, yolk height (mm) and haugh unit in laying hens

	Week	Control	Lupin (%)			SEM	*P*-value		
			11	16.5	22		control vs lupins[1]	linear[2]	quadratic
Yolk colour	1	8.6	8.3	8.8	8.8	0.1	0.99	0.07	0.16
	2	8.7	8.6	8.8	8.8	0.1	0.88	0.42	0.80
	3	8.7	8.7	8.7	8.9	0.1	0.57	0.25	0.55
	4	8.6	8.6	8.7	8.8	0.1	0.94	0.41	0.41
	5	8.6	8.6	8.8	9.0	0.1	0.31	0.01	0.22
	6	8.5	8.7	8.6	8.8	0.1	0.12	0.16	0.79
	7	8.5	8.3	8.4	8.5	0.1	0.73	0.65	0.32
	8	8.4	8.3	8.4	8.6	0.1	0.90	0.30	0.14
	9	8.4	8.7	8.7	8.7	0.1	0.02	0.06	0.12
	1–9	8.6	8.5	8.7	8.8	0.1	0.54	0.26	0.37
Yolk height	1	9.12	9.04	8.89	9.14	0.15	0.55	0.88	0.25
	2	9.22	9.01	9.29	9.15	0.14	0.63	0.92	0.78
	3	9.08	8.96	9.19	9.24	0.09	0.62	0.08	0.36
	4	9.05	8.93	9.14	9.04	0.06	0.81	0.52	0.81
	5	9.02	8.93	9.14	9.04	0.07	0.86	0.42	0.97
	6	9.05	8.88	9.06	9.00	0.07	0.36	0.93	0.39
	7	9.00	8.95	9.06	9.16	0.07	0.48	0.06	0.25
	8	8.95	8.87	8.84	9.04	0.08	0.71	0.49	0.07
	9	9.01	9.15	9.15	9.07	0.08	0.19	0.61	0.14
	1–9	9.06	8.97	9.08	9.10	0.09	0.57	0.52	0.42
Haugh unit	1	95.1	94.8	94.4	94.8	0.7	0.57	0.68	0.57
	2	95.1	94.8	94.4	94.8	0.7	0.57	0.68	0.57
	3	94.8	94.3	95.0	94.9	0.9	0.99	0.79	0.86
	4	95.2	95.3	94.9	95.0	0.8	0.84	0.74	0.98
	5	95.2	95.3	95.0	95.1	0.6	0.95	0.81	0.94
	6	94.7	94.8	94.4	94.1	0.7	0.70	0.42	0.73
	7	94.6	94.5	95.2	95.4	0.4	0.40	0.12	0.70
	8	95.0	94.9	95.6	95.8	0.7	0.61	0.33	0.81
	9	94.4	95.3	94.6	94.7	0.5	0.41	0.89	0.43
	1–9	94.9	94.9	94.8	95.0	0.7	0.72	0.61	0.72

[1]Orthogonal contrast to test control diet vs all lupin supplementation diets

[2]Orthogonal polynomial contrast coefficients were used to determine the linear and quadratic effect of increasing dietary lupin supplementation levels

week experiment: hen per day egg production was higher than 90% and feed intake was approximately 120 g/hen per day (Perez-Maldonado et al. 1999). In another study, feed supplemented with up to 30% white lupin in diets resulted in good egg production (Prinsloo et al. 1992). However, negative effects of lupin diets on egg production performance have also been reported. Laying hens fed diets with 25 and 30% white lupin had a lower egg mass compared with hens on a lupin-free diet (Watkins and Mirosh 1987). Moreover, a 25% lupin diet exerted significant negative effects on performance, egg weight, and daily egg mass (Hammershoj and Steenfeldt 2005).

The results of the present study showed that laying hens fed different concentrations of lupin exhibited linearly improved egg yolk colour at five weeks ($P = 0.01$; Table 9). Egg yolk colour in laying hens is one of the major parameters for the quality of an egg and is an important criterion for consumers (Teoh et al. 2015). Egg yolk colour is correlated with pigment content and ranges from yellow (e.g., lutein, zeaxanthin, apo-ester) to red (e.g., canthaxanthin, citraxanthin, astaxanthin)

doi: 10.17221/330/2014-VETMED

due to carotenoids or xanthophylls in the hen's diet (Beardsworth and Hernandez 2004; Roberts 2004). Various efforts have focused on the use of suitable feeds to enhance egg yolk colour. The substitution of soy bean meal with low-fibre alfalfa (*Medicago sativa* L.) meal improved yolk colour, yolk percentage, yolk cholesterol, and β-carotene contents in hen diets (Laudadio et al. 2014). The use of yellow lupin seed meal in the feeding mixture resulted in a more distinct yellow/red egg yolk (Dvorak et al. 2007). In addition, defatted diatom microalgal biomass diet in laying hens increased the egg albumen weight and height compared with 7.5% defatted diatom microalgal biomass diets (Leng et al. 2014).

In conclusion, the present study indicates that diets supplemented with lupin could improve egg production performance and egg yolk quality, while it apparently had no effect on eggshell quality in laying hens. Further investigations are necessary to explore the effects of lupin on the immune response in laying hens.

REFERENCES

AOAC – Association of Official Analytical Chemists (2012): Official Methods of Analysis. 19th edn. Association of Official Analytical Chemists, Gaithersburg.

Beardsworth PM, Hernandez JM (2004): Yolk colour – An important egg quality attribute. International Poultry Production 12, 17–18.

Boschin G, D'Agostina A, Annicchiarico P, Arnoldi A (2008): Effect of genotype and environment on fatty acid composition of Lupinus albus L. seed. Food Chemistry 108, 600–606.

Donovan BC, Mcniven MA, Vanlunen TA, Anderson DM, Macleod JA (1993): Replacement of soybean-meal with dehydrated lupin seeds in pig diets. Animal Feed Science and Technology 43, 77–85.

Dvorak P, Strakova E, Kunova J, Kunova V (2007): Egg yolk colour depends upon the composition of the feeding mixture for laying hens. Acta Veterinaria Brno 76, 121–127.

Glencross BD, Carter CG, Duijster N, Evans DR, Dods K, McCafferty P, Hawkins WE, Maas R, Sipsas S (2004): A comparison of the digestibility of a range of lupin and soybean protein products when fed to either Atlantic salmon (Salmo salar) or rainbow trout (Oncorhynchus mykiss). Aquaculture 237, 333–346.

Hammershoj M, Steenfeldt S (2005): Effects of blue lupin (Lupinus angustifolius) in organic layer diets and supplementation with foraging material on egg production and some egg quality parameters. Poultry Science 84, 723–733.

Hove EL (1974): Composition and protein quality of sweet lupin seed. Journal of the Science of Food and Agriculture 25, 851–859.

Lampart-Szczapa E, Korczak J, Nogala-Kalucka M, Zawirska-Wojtasiak R (2003): Antioxidant properties of lupin seed products. Food Chemistry 83, 279–285.

Laudadio V, Tufarelli V (2010): Growth performance and carcass and meat quality of broiler chickens fed diets containing micronized-dehulled peas (Pisum sativum cv. Spirale) as a substitute of soybean meal. Poultry Science 89, 1537–1543.

Laudadio V, Tufarelli V (2011a): Influence of substituting dietary soybean meal for dehulled-micronized lupin (Lupinus albus cv. Multitalia) on early phase laying hens production and egg quality. Livestock Science 140, 184–188.

Laudadio V, Tufarelli V (2011b): Dehulled-micronised lupin (Lupinus albus L. cv. Multitalia) as the main protein source for broilers: influence on growth performance, carcass traits and meat fatty acid composition. Journal of the Science of Food and Agriculture 91, 2081–2087.

Laudadio V, Ceci E, Lastella NMB, Introna M, Tufarelli V (2014): Low-fiber alfalfa (Medicago sativa L.) meal in the laying hen diet: Effects on productive traits and egg quality. Poultry Science 93, 1868–1874.

Leng XJ, Hsu KN, Austic RE, Lei XG (2014): Effect of dietary defatted diatom biomass on egg production and quality of laying hens. Journal of Animal Science and Biotechnology 5, 3.

Martinez-Villaluenga C, Frias J, Vidal-Valverde C (2006): Functional lupin seeds (Lupinus albus L. and Lupinus luteus L.) after extraction of alpha-galactosides. Food Chemistry 98, 291–299.

Nalle CL, Ravindran V, Ravindran G (2011): Nutritional value of narrow-leafed lupin (Lupinus angustifolius) for broilers. British Poultry Science 52, 775–781.

NRC – National Research Council (1994): Nutrient Requirements of Swine. 9th edn. National Academies Press, Washington. 420 pp.

Perez-Maldonado RA, Mannion PE, Farrell DJ (1999): Optimum inclusion of field peas, faba beans, chick peas and sweet lupins in poultry diets. I. Chemical composition and layer experiments. British Poultry Science 40, 667–673.

Prinsloo JJ, Smith GA, Rode W (1992): Sweet white Lupinus-Albus (cv Buttercup) as a feedstuff for layers. British Poultry Science 33, 525–530.

Ravindran V, Blair R (1992): Feed resources for poultry production in Asia and the Pacific. II. Plant protein sources. World's Poultry Science Journal 48, 205–231.

doi: 10.17221/330/2014-VETMED

Roberts JR (2004): Factors affecting egg internal quality and egg shell quality in laying hens. Journal of Poultry Science 41, 161–177.

Rothmaier DA, Kirchgessner M (1994): White lupins (Lupinus-Albus, L) as a replacement for soybean-meal in diets for fattening chickens. Archiv fur Geflugelkunde 58, 111–114.

Rubio LA, Brenes A, Centeno C (2003): Effects of feeding growing broiler chickens with practical diets containing sweet lupin (Lupinus angustifolius) seed meal. British Poultry Science 44, 391–397.

SAS Institute (1996): SAS User's Guide: Statistics. Version 7.0. SAS Institute Inc., Cary.

Schamsschargh M, Zollitsch W, Knaus W, Lettner F (1994): The use of lupins in poultry diets. Die Bodenkultur 45, 163–175.

Suchy P, Strakova E, Herzig I, Steinhauser L, Vopalensky J, Kroupa L (2010): Effect of replacing soybean meal with lupin seed-based meal in chicken diet on performance, carcass value and meat quality. Acta Veterinaria Brno 79, 195–202.

Teoh JY, Kasim A, Omar H, Loh TC, Cheong DSW (2015): Effect of spent pink guava mesocarp meal on performance and egg quality in laying hens. International Journal of Livestock Research 5, 37–44.

Vicenti A, Toteda F, Di Turi L, Cocca C, Perrucci M, Melodia L, Ragni M (2009): Use of sweet lupin (Lupinus albus L. var. Multitalia) in feeding for Podolian young bulls and influence on productive performances and meat quality traits. Meat Science 82, 247–251.

Viveros A, Centeno C, Arija I, Brenes A (2007): Cholesterol-lowering effects of dietary lupin (Lupinus albus var multolupa) in chicken diets. Poultry Science 86, 2631–2638.

Watkins BA, Mirosh LW (1987): White lupin as a protein source for layers. Poultry Science 66, 1798–1806.

Yan L, Meng QW, Ao X, Wang JP, Jang HD, Kim IH (2011): Evaluation of dietary wild-ginseng adventitious root meal on egg production, egg quality, hematological profiles and egg yolk fatty acid composition in laying hens. Livestock Science 140, 201–205.

Received: 2014–10–27
Accepted after corrections: 2016–09–30

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