Use of semi-leafless peas (*Pisum sativum* L) in laying hen diets

Erja Koivunen[1], Petra Tuunainen[1], Eija Valkonen[2], Jarmo Valaja[3]

[1]Luke Natural Resources Institute Finland, Green Technology, Pig and Poultry Production, 31600 Jokioinen, Finland

[2] Hankkija Oy, P.O. Box 390, 05801 Hyvinkää, Finland

[3] Department of Agricultural Sciences, P.O. Box 28, University of Helsinki, 00014, Finland
e-mail: erja.koivunen@luke.fi

The study was conducted to evaluate an appropriate inclusion level of white-flowered semi-leafless green spring peas in diets for laying hens. Egg production and egg quality variables (specific weight, Haugh unit, shell strenght) were determined with 576 hens in a 52-week feeding experiment, which comprised of three feeding phases. The hens were offered one of the four cereal and soybean meal (SBM) based experimental diets. Peas were tested in proportions of 0, 100, 200 or 300 g kg^{-1} in the diet. Pea inclusion had no effects on production performance, feed consumption or feed conversion ratio (FCR) of the hens during the entire trial. The pea inclusion impaired FCR during the second feeding phase ($p < 0.05$) and increased birds' live weight in a linear manner during the second and the third feeding phases ($p < 0.05$). Pea inclusion had no effects on egg quality. It can be concluded that at least 300 g kg^{-1} of the studied peas can be used in the diets of laying hens without negative effects on production performance or egg quality.

Key words: egg production, egg quality, feed, laying hen, pea

Introduction

Imported soybean meal (SBM) is the main protein source used in poultry feed in Europe. In those climates, where soybean (*Glycine max*) cannot be produced or its production is not economical, there is a strong interest in maximizing the use of locally produced protein sources, like peas (*Pisum sativum* L.), as a substitute for imported SBM. The use of domestic legumes like peas offers the possibility to improve self-sufficiency in protein-rich feedstuffs (Gatel 1994). In addition, to increase the production of locally produced protein sources is also a way to diversify northern cropping system dominated by cereals (Peltonen-Sainio et al. 2013). A lot of area is also favorable for crop based protein production from legumes (Peltonen-Sainio et al. 2013). Peas have an important role in the crop rotation due to their ability to fix nitrogen (Stoddard et al. 2009). Because of that, growing peas has a special function in organic farming (Stoddard et al. 2009).

Pea supplies both energy and protein in poultry diets (Rodrigues et al. 2012). Gatel (1994) stated that pea protein is as rich in lysine as SBM protein. Pea protein contains a similar proportion of threonine, but less sulfur containing amino acids and tryptophan than SBM protein (Gatel 1994). Compared to cereals, pea is a good source of lysine, but the sulphur containing amino acids methionine and cysteine and also tryptophan are present at low levels in the protein of peas (Gatel 1994). However, considering the protein amino acid profile of cereals and peas, they complement each other well (Gatel 1994). In addition, shortages in the amino acid composition of peas are easy to compensate with feed grade crystalline amino acids in conventional poultry diets (Fru-Nji et al. 2007).

The main anti-nutritional factors (ANF) present in the peas are protease inhibitors, lectins and tannins, which have an adverse effect on protein digestibility (Gatel 1994). Owing to the high variability in ANF within the pea cultivar it has been possible to improve their nutritional value by selective breeding (Gatel 1994).

High levels of unprocessed peas at a level of 250 – 500 g kg^{-1} in a laying hen diet have been demonstrated to support good production (Ivusic et al. 1994, Perez-Maldonado et al. 1999, Fru-Nji et al. 2007). Fru-Nji et al. (2007) reported no differences in egg quality between diets that contained up to level of 500 g kg^{-1} of peas. Anderson (1979) and Ivusic et al. (1994) showed that diets containing 300 – 590 g kg^{-1} of peas had an adverse effect on egg shell quality.

There is a need to evaluate the nutritive values of locally produced and currently available pea cultivars, and to find their optimal inclusion levels in poultry diets. The aim of this study was to find an appropriate inclusion level of white-flowered semi-leafless green spring peas (cv. Karita) in SBM and cereal-based diets for laying hens. A further aim was to study the effects of dietary pea inclusion on specific weight, Haugh unit and shell strenght.

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Materials and methods

Experimental animals and treatments

A total of 576 Leghorn chickens (Lohmann Selected Leghorn, LSL Classic) aged 21 weeks were randomly assigned to 32 replicates, with six cages per replicate and three hens per conventional cage, offering 660 cm^2 cage area per hen. The replicates were randomly assigned to four different dietary treatments, yielding eight replicates per treatment. During the trial, each photoperiod lasted 14.5 hours and scotoperiod 9.5 hours. The temperature in the hen house was kept at 20 °C. The study was approved by the Local Ethical Committee for Animal Experiments.

A diet based on cereals and SBM served as control (Table 1). A variety of white-flowered semi-leafless green spring pea seeds cv. Karita (Lantmännen SW 1995) was included at 100 g kg^{-1}, 200 g kg^{-1} and 300 g kg^{-1} of diet (18.1, 37.1 or 56.9% of soybean meal was replaced by peas). The experiment lasted 52 weeks (a whole laying period), and it comprised of three feeding phases and was divided to 13 four-week periods. The first feeding phase lasted for five periods (20 weeks) and second and third feeding phases lasted for four periods (both of them 16 weeks). The diets within the different feeding phases were aimed to formulate to contain equal amounts of crude protein, lysine, methionine, threonine, calcium and available phosphorus per MJ of AME using table values for feed ingredients published in the Finnish Feed Tables and Nutrient Requirements (Luke 2014) and to meet the nutrient requirements of LSL Classic hens (Lohmann 2010). The nutrient contents of diets were equalized with rapeseed oil, amino acids and monocalcium phosphate. The feed ingredients were ground in a roller mill (Gehl Company, West Bend, Wisconsin, USA). The feeds were mixed and cold-pelleted (Amandus Kahl Laborpresse 1175, Germany). Feed and water were available *ad libitum* throughout the experiment.

Table 1. Composition of experimental diets (g kg^{-1})

	Experimental diets 21 – 41 weeks of age				Experimental diets 41 – 57 weeks of age				Experimental diets 57 – 73 weeks of age			
	Control	Pea inclusion g kg^{-1}			Control	Pea inclusion g kg^{-1}			Control	Pea inclusion g kg^{-1}		
		100	200	300		100	200	300		100	200	300
Barley	258	232	207	181	287	258	231	202	330	298	276	244
Wheat	258	232	206	181	199	179	160	140	114	102	70	55
Oat	257	231	206	181	287	258	231	202	330	297	275	244
Soybean meal	116	95	73	50	116	94	71	49	116	94	72	50
Pea	–	100	200	300	–	100 0	200	300	–	100	200	300
Rapeseed oil	1.0	1.1	1.0	–	1.0	1.1	–	–	–	–	–	–
Monocalcium phosphate	19	19	18	18	19	19	18	18	19	19	18	18
Limestone	81	80	80	80	81	80	80	80	81	80	80	80
Salt	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Mineral premix[1]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin premix[2]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
DL-Methionine	1.1	1.5	1.5	1.5	1.1	1.5	1.5	1.5	1.1	1.2	1.3	1.4
L-Lysine	1.0	1.0	–	–	1.0	1.0	–	–	1.0	1.0	–	–

[1] Providing the following per kg of feed: Ca 0.6 g, Fe 25 mg, Cu 8 mg, Mn 50 mg, Zn 65 mg, I 0.5 mg, Se 0.2 mg

[2] Providing the following per kg of feed: Ca 2.4 g, vitamin A 23.958 IU (retinol), vitamin D_3 5.476 IU, vitamin E 61.6 mg (α-tokopherol 56.1 mg), vitamin K_3 10.5 mg, vitamin B_1 4.8 mg, vitamin B_2 10.5 mg, vitamin B_6 7.4 mg, vitamin B_{12} 0.04 mg, biotin 0.4 mg, folic acid 1.3 mg, niacin 84.2 mg, pantothenic acid 21.1 mg, canthaxanthin 5.7 mg

Analytical and experimental procedures

Feed samples were taken from every batch made and then pooled. The pooled samples were passed through a hammer mill fitted with a 1-mm mesh prior to analysis. Crude fat and ash contents were determined by standard methods (AOAC, 1990, methods 942.05 and 920.39). Crude fiber content was determined with a modified method (AOAC method 962.09) using glass wool instead of ceramic filters. The nitrogen content was analyzed using a Leco FP 428 nitrogen analyser (Leco Corporation, St. Joseph, MI). The crude protein content was calculated by multiplying the nitrogen content by 6.25. Amino acid content (excluding tryptophan, which was not determined) was analyzed using accredited In-house method No. 5000 (EC 1998). Total (peptide bound and free) amino acid analysis was performed with Waters Finland MassTrak UPLC (Waters Corporation, Milford, USA) and the application was UPLC Amino Acid Analysis Solution®. The calcium and phosphorus concentrations were determined with an ICP emission spectrophotometer (Thermo Jarrel Ash-Baird, Franklin, MA; Luh Huang and Schulte 1985).

Egg weight and number were recorded daily, and the mean production variables were calculated for each four-week period. The feed consumption was measured in each period. Mortality was recorded daily. Cumulative mortality was calculated at the end of the experiment. The hens were weighed when they were 21-, 41-, 56-, and 72 weeks old.

Egg quality variables; specific weight, Haugh unit, shell strength were examined once per each feeding phase at the age of 36-, 54 and 68- weeks old. The egg quality variables were measured in eight eggs per replicate. The specific weight was based on Archimedes' principle for assessment of the specific gravity of eggs (Hamilton, 1982). Albumen height was measured with a digital tripod micrometer (York Electronic Centre, Technical Services and Supplies Limited, York, England) and converted to Haugh units. The shell-breaking force (shell strength) was measured as compressive fracture force using an eggshell tester of the OTAL Precision Company Limited, Ottawa, ON, Canada (Hamilton 1982).

Statistical analyses

Production performance data was subjected to repeated-measures ANOVA using the GLM procedure of SAS (SAS Institute Inc., Cary, NC, USA) and the following model: $Y_{ijk} = \mu + t_i + \delta_i + p_j + (p \times t)_{ij} + \varepsilon_{ijk}$, where Y_{ijk} = observation, μ = the general mean, t_i = the effect of the treatment (i = 1, …,4), δ_i = the error term for the effect of the treatment i, p_j = the effect of the period (j= 1,…,13), and ε_{ijk} = the experimental error term. The egg quality variables, birds' live weight, and - growth were analyzed using the following model: $Y_{ij} = \mu + t_i + \varepsilon_{ik}$, where Y_{ij} = observation, μ = the general mean, t_i = the effect of the treatment (i = 1, …,4), and ε_{ijk} = the experimental error term. The treatment effects for the three feeding phases were separated into three polynomial contrasts: the linear, quadratic and cubic effect of dietary pea inclusion (P_{linear}, $P_{quadratic}$, $P_{cubic)}$. Because the cubic effect was not significant it was removed. In the current study, $p \leq 0.05$ was considered to be significant.

Results

The diets within different feeding phases were from practical point of view similar in their nutrient content (Table 2). The experiment lasted 52 weeks (a whole laying period), and it comprised of three feeding phases and was divided to 13 four-week periods. The first feeding phase lasted for five periods (20 weeks) and second and third feeding phases lasted for four periods (both of them 16 weeks). The diets within the different feeding phases were aimed to formulate to contain equal amounts of crude protein, lysine, methionine, threonine, calcium and available phosphorus per MJ of AME using table values for feed ingredients published in the Finnish Feed Tables and Nutrient Requirements (Luke 2014) and to meet the nutrient requirements of LSL Classic hens (Lohmann 2010). The nutrient contents of diets were equalized with rapeseed oil, amino acids and monocalcium phosphate. The feed ingredients were ground in a roller mill (Gehl Company, West Bend, Wisconsin, USA). The feeds were mixed and cold-pelleted (Amandus Kahl Laborpresse 1175, Germany). Feed and water were available *ad libitum* throughout the experiment.

Table 2. Calculated and analyzed chemical composition of the experimental diets (g kg $^{-1}$DM), except AME and DM

	Experimental diets 21 – 41 weeks of age				Experimental diets 41 – 57 weeks of age				Experimental diets 57 – 73 weeks of age			
	Control	Pea inclusion g kg $^{-1}$			Control	Pea inclusion g kg $^{-1}$			Control	Pea inclusion g kg $^{-1}$		
		100	200	300		100	200	300		100	200	300
Calculated composition												
AME, MJ/kg	11.5	11.6	11.6	11.6	11.4	11.5	11.5	11.5	11.3	11.3	11.3	11.3
Crude protein	162.9	163.2	163.5	163.1	161.0	161.3	161.5	161.6	158.5	159.1	159.1	159.4
Lysine	8.2	8.7	8.6	8.7	8.2	8.7	8.3	8.7	8.3	8.8	8.4	8.8
Methionine	3.9	4.2	4.1	4.0	3.9	4.2	4.1	4.0	3.9	3.9	3.8	3.8
Methionine + cysteine	7.4	7.6	7.3	7.1	7.3	7.5	7.3	7.0	7.3	7.2	7.1	6.9
Threonine	5.9	6.0	6.1	6.2	5.9	6.0	6.1	6.1	5.9	6.0	6.1	6.2
Calcium	38.8	38.4	38.2	38.3	38.8	38.4	38.3	38.3	38.9	38.5	38.3	38.4
Phosphorus (available)[1]	4.7	4.8	4.6	4.7	4.7	4.8	4.6	4.7	4.7	4.8	4.7	4.7
Analyzed composition												
DM, g/kg	918.0	909.4	905.7	907.8	895.8	895.1	891.3	888.9	890.9	890.9	889.7	888.3
Crude protein	177.3	176.7	174.9	173.8	163.7	168.2	163.7	167.2	174.2	178.1	176.6	169.5
Crude fat	28.9	27.7	26.1	23.1	28.0	28.2	23.2	22.0	28.2	25.8	24.5	24.6
Crude fiber	59.8	48.6	52.2	51.8	59.2	63.6	55.8	62.8	66.1	65.4	40.8	62.2
Ash	136.4	132.6	129.9	133.6	115.1	128.7	138.6	124.1	120.7	132.0	129.0	130.1
Alanine	7.1	7.2	7.3	7.5	6.6	7.6	7.2	7.3	7.8	8.1	8.5	8.1
Arginine	9.8	10.5	10.5	11.2	10.4	11.5	12.1	11.6	11.5	13.1	12.2	11.7
Aspartic acid	13.9	15.4	15.3	16.3	13.0	15.6	17.0	15.9	15.8	17.1	17.7	18.2
Cysteine	3.5	3.5	3.3	3.3	3.8	3.8	3.4	3.8	3.7	4.1	3.8	3.1
Glutamic acid	41.4	41.3	39.1	37.3	34.6	36.7	38.1	35.3	41.1	41.6	40.8	39.1
Glycine	7.4	7.6	7.5	7.5	6.8	7.7	7.6	7.5	7.8	8.2	8.4	8.1
Histidine	4.3	4.3	4.3	4.1	4.2	4.5	4.1	4.3	4.4	4.8	4.6	4.2
Isoleucine	6.4	6.5	6.1	6.7	6.3	6.8	6.4	6.4	7.0	7.1	7.0	6.8
Leucine	12.6	12.6	12.7	12.3	12.8	13.5	12.9	13.1	13.8	14.4	14.1	13.3
Lysine	8.1	8.7	8.7	9.2	7.6	8.9	9.3	8.9	8.9	9.8	9.3	9.4
Methionine	3.5	4.2	3.8	3.9	3.6	3.7	3.8	3.6	3.5	4.1	4.0	3.5
Phenylalanine	8.4	8.5	8.2	8.3	8.0	8.8	8.1	8.4	9.3	9.5	9.4	8.9
Proline	13.5	12.2	11.7	10.8	12.2	11.7	10.9	11.5	11.9	14.1	12.7	9.6
Serine	8.1	8.5	8.3	8.4	7.6	9.2	8.9	8.2	9.5	9.7	9.6	8.9
Treonine	5.5	6.1	6.0	6.3	5.5	6.4	6.6	6.0	6.6	6.8	6.8	6.6
Valine	7.1	7.1	6.9	7.8	7.7	8.5	7.8	7.9	8.5	8.7	8.5	8.2
Calcium	43.8	41.3	39.3	42.1	33.6	37.4	41.5	36.5	36.1	39.8	39.1	39.1
Phosphorus	8.9	8.9	8.4	8.8	7.7	8.4	8.9	8.5	8.0	8.6	8.4	8.0

AME = apparent metabolizable energy
DM = dry matter
[1] based on Finnish Feed tables and nutrient requirements (Luke 2014)

Nutrient content in feed ingredients to some extent varied during the experiment (52 weeks). Hence the diets were not totally isonitrogenonous and amino acid contents slightly varied. The pea cultivar used in the current study contained 217 g kg^{-1} DM crude protein (Table 3).

Table 3. Analysed chemical composition of SBM and pea (g kg $^{-1}$ DM), except DM[1]

	SBM	Pea
DM, g kg^{-1}	876	875
Crude protein	530	217
Crude fat	14.8	14.0
Crude fibre	40.7	55.4
Ash	71.2	33.8
Nitrogen-free extract	344	680

[1] based on single analyses
DM = dry matter
SBM = soybean meal

Dietary pea inclusion had no effects on the production performance, feed consumption or feed conversion ratio (FCR) of the hens during the entire trial. The only significant difference among production performance variables studied was a linear manner impaired FCR during the second feeding phase (41 – 57 weeks of age) ($p < 0.05$) (Table 4).

Table 4. The effects of dietary inclusion level of peas on laying hen egg production variables[1]

	Pea inclusion, g kg $^{-1}$					p-values	
	Control	100	200	300	SEM	p_{linear}	$p_{quadratic}$
Egg production, %							
21 – 73 weeks of age	93.4	93.1	93.3	92.1	3.03	0.388	0.631
21 – 41 weeks of age	96.1	95.7	96.1	95.5	1.57	0.696	0.233
41 – 57 weeks of age	95.4	94.7	95.2	94.0	1.96	0.210	0.671
57 – 73 weeks of age	89.0	89.5	89.0	88.0	2.33	0.506	0.534
Egg weight, g							
21 – 73 weeks of age	65.6	65.1	65.2	65.5	1.08	0.909	0.187
21 – 41 weeks of age	62.0	61.4	61.7	61.8	0.64	0.995	0.233
41 – 57 weeks of age	64.1	63.5	63.7	63.9	0.69	0.842	0.143
57 – 73 weeks of age	68.9	68.7	68.7	69.2	0.63	0.512	0.265
Egg mass production, g/hen per d							
21 – 73 weeks of age	61.2	60.5	60.8	60.3	1.95	0.403	0.869
21 – 41 weeks of age	59.6	58.8	59.4	59.0	0.92	0.627	0.587
41 – 57 weeks of age	61.1	60.1	60.6	60.0	1.32	0.186	0.765
57 – 73 weeks of age	61.3	61.5	61.1	60.9	1.60	0.670	0.813
Feed consumption, g/hen per d							
21 – 73 weeks of age	129	129	130	130	3.3	0.433	0.900
21 – 41 weeks of age	122	122	123	124	1.6	0.062	0.296
41 – 57 weeks of age	127	127	128	129	2.1	0.318	0.790
57 – 73 weeks of age	135	134	135	134	2.8	0.739	0.825
FCR, g of feed/g of egg							
21 – 73 weeks of age	2.12	2.14	2.14	2.16	0.075	0.179	0.993
21 – 41 weeks of age	2.05	2.07	2.07	2.10	0.040	0.102	0.774
41 – 57 weeks of age	2.08	2.12	2.11	2.14	0.046	0.038	0.672
57 – 73 weeks of age	2.20	2.18	2.21	2.20	0.058	0.742	0.897
Cumulative mortality, %							
21 – 73 weeks of age	3.47	3.47	9.03	4.86	1.911	0.179	0.245

[1] Values are means of 8 replicates per treatment and they represent the means of the values of 13, 5, 4 or 4 periods (4 weeks each)
FCR = feed conversion ratio

Birds' live weight increased in a linear manner along pea inclusion during the second and third feeding phases (41 – 57 and 57 – 73 weeks of age) ($p < 0.05$) (Table 5).

Table 5. The effects of dietary inclusion level of peas on the mean live weight and change in live weight of laying hens[1]

	Pea inclusion, g kg $^{-1}$					p-values	
	Control	100	200	300	SEM	p_{linear}	$p_{quadratic}$
Live weight, g							
21 weeks of age	1542	1550	1547	1578	9.0	0.145	0.593
41 weeks of age	1798	1809	1788	1829	12.8	0.302	0.239
56 weeks of age	1839	1868	1871	1893	16.1	0.037	0.796
72 weeks of age	1869	1915	1921	1935	18.5	0.027	0.391
Growth, g							
21 – 41 weeks of age	256	258	241	251	9.2	0.357	0.695
41 – 56 weeks of age	41.0	60.0	84.0	64.0	11.10	0.058	0.088
56 – 72 weeks of age	31.0	47.0	49.0	42.0	9.90	0.431	0.239

[1] Values are means of 8 replicates per treatment and represent the mean values

The egg quality variables studied; specific weight, Haugh unit and shell strength were similar among the all feeding treatments with the exception in a quadratic manner decreased specific weight along pea inclusion examined during the second feeding phase (41 – 57 weeks of age) ($p < 0.05$) (Table 6).

Table 6. The effects of dietary inclusion level of peas on egg quality variables[1]

	Pea inclusion, g kg $^{-1}$					p-values	
	Control	100	200	300	SEM	p_{linear}	$p_{quadratic}$
Specific weight							
36 weeks of age	1.086	1.085	1.085	1.086	0.0006	0.608	0.386
54 weeks of age	1.086	1.085	1.085	1.086	0.0005	0.084	0.012
68 weeks of age	1.077	1.078	1.077	1.076	0.0006	0.444	0.209
Haugh unit							
36 weeks of age	91.1	90.7	90.9	90.8	0.85	0.897	0.878
54 weeks of age	87.2	88.6	87.8	87.7	0.65	0.918	0.270
68 weeks of age	82.1	83.2	82.8	81.6	0.91	0.680	0.216
Shell strength, kg							
36 weeks of age	3.70	3.88	3.85	3.81	0.111	0.596	0.328
54 weeks of age	3.59	3.65	3.60	3.45	0.076	0.172	0.174
68 weeks of age	3.14	2.98	3.06	3.06	0.066	0.848	0.460

[1] Values are means of 8 replicates per treatment (each observation is a mean of 8 eggs per experimental unit) and represent the mean values.

Discussion

Crude protein content of studied batch of peas (217 g kg^{-1} DM) was comparable with previous reports using the same pea variety (Partanen et al. 2001, Partanen et al. 2006). As expected the crude protein content of semi-leafless peas was lower than for instance reported for ordinary field peas (243 g kg^{-1} DM) (Partanen et al. 2001, Rodrigues et al. 2012). Protein content of peas is known to vary greatly between cultivar with a range from 181 to 436 g kg^{-1} DM (Gatel and Grosjean 1990). The average crude protein content of peas is lower than that of faba beans (300 g kg^{-1} DM) and lupins (340 g kg^{-1} DM) (Luke 2014), which are other potential home-grown grain legumes (Palander et al. 2006).

In the current study the diet that included up to 300 g kg^{-1} of peas supported a good production. The egg production variables were comparable to earlier studies with high inclusion levels of peas (Castanon and Perez-Lanzac 1990, Ivusic et al. 1994, Perez-Maldonado et al. 1999, Fru-Nji et al. 2007). Compared with control diet Castanon and Perez-Lanzac (1990), Ivusic et al. (1994), Perez-Maldonado et al. (1999) and Fru-Nji et al. (2007) reported no significant difference in egg production variables, including up to 333 g kg^{-1}, 445 g kg^{-1}, 500 g kg^{-1} or 250 g kg^{-1} of peas (respectively). Castanon and Perez-Lanzac (1990) studied cull peas orginate from a surplus in the canning industry, so the results of their study are not totally comparable with our results.

In the diet that included up to 300 g kg^{-1} of peas, the protein from peas was able to replace approximately 44% of the protein from SBM. There are several other studies showing that SBM protein can be replaced by pea protein (Castanon and Perez-Lanzac 1990, Perez-Maldonado et al. 1999, Fru-Nji et al. 2007). However, the additional methionine was needed to avoid reduction in production performance, when peas were included to the diet in line with literature (Perez-Maldonado et al. 1999, Fru-Nji et al. 2007). However, the necessary amount of added methionine is dependent on the content of methionine in feed ingredients used and the crude protein content achieved.

Based on the results of production performance and egg quality, peas had no adverse effect. This indicated that the studied pea cultivar did not contain harmful levels of ANF. This is in line with Smulikowska et al. (2001), who reported that the role of trypsin- and protease inhibitors in modern spring cultivars of pea are found to be less important. Seeds of coloured-flowered cultivars, which are rich in tannins are less effectively utilized by poultry than white-flowered ones (Smulikowska et al. 2001, Rodrigues et al. 2012).

The linear increase in FCR and live weight with increasing pea inclusion during the second feeding phase (41 – 57 weeks of age) was unexpected and indicates that weight gain was prioritized over egg production during this period as feed intake remained unchanged. However, these findings remain unexplained. In agreement with the current results Ivusic et al. (1994), and Igbasan and Guenter (1997) reported no differences in mortality between the control and diets with pea inclusion.

The dietary pea inclusion had a significant effect on specific weight, but from a practical point of view the difference observed is irrelevant. Our results on the egg quality variables agree with the results of Anderson (1979) and Fru-Nji et al. (2007). Anderson (1979) found no significant differences in egg quality variables (albumen quality, yolk colour and chemical composition) between control diet and diet included up to 300 g kg^{-1} of peas, but showed that pea inclusion (300 g kg^{-1}) had an adverse effect egg shell quality. Fru-Nji et al. (2007) found no significant difference in egg quality variables (shell strength, shell fraction, yolk fraction, yolk index, yolk colour, albumen fraction, albumen index) in diets with up to 250 g kg^{-1} of peas. However, Ivusic et al. (1994) reported that feeding diets with 590 g peas per kg of feed resulted in eggs with thinner shells and with reduced yolk pigmentation.

In conclusion, when diets are balanced with regards to their nutrient content at least 300 g kg^{-1} semi-leafless peas studied can be used in laying hen diets based on cereals and SBM, without negative effects on the production performance and egg quality.

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