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Egg performance, egg quality, and nutrient utilization in laying hens fed diets with different levels of rapeseed expeller cake

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The aim of this study was to evaluate the effect of different levels of rapeseed expeller cake (RC) in the diet of laying hens on egg performance, egg quality, retention and excretion of nitrogen, calcium and phosphorus, and metabolizability of energy. The experiment was carried out with 72 Bovans Brown hens, from 28 to 53 weeks of age. Experimental treatment consisted of four isonitrogenous and isocaloric corn-soybean diets (as calculated: 17% crude protein, 11.6 MJ/kg metabolizable energy, 0.81% lysine, 0.36% methionine, 3.60% calcium and 0.37% available phosphorus), containing 0, 4, 6 or 8% RC. The RC used was produced from double zero rapeseed and contained 29.3% crude protein, 17.4% crude fat, 10.8% crude fibre, 0.63% calcium, 0.97% phosphorus, 1.91% lysine and 0.84% methionine. During the experimental period, the dietary level of RC had no significant effects on egg performance and egg quality parameters. Boiled eggs from hens fed a diet with 8% RC were characterized by an inferior flavour to those from other groups. There were no treatment effects on nitrogen balance or metabolizability of energy, though the highest dietary level of RC negatively affected retention and excretion of calcium and phosphorus.

Key-words: rapeseed expeller cake, laying hens, egg performance, egg quality, nutrient retention

Introduction

Rapeseed expeller cake (RC) is a high-protein co-product of industrial oil extraction, obtained from the mechanical pressing of seeds. In recent years in central and northern Europe, this method of oil extraction has come to be used, especially in the production of biodiesel. As biodiesel is a renewable source of energy, and burns with low carbon dioxide emissions, global production of biodiesel from vegetable oils continues to increase rapidly, and further large growth is expected in the future.

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This growth will result in an enlarged quantity of RC available to feed producers. The European Union has supported biofuels production in order to diversify energy supplies, reduce greenhouse gas emission and dependency on oil and to create additional employment in rural areas (Świątkiewicz and Koreleski 2008)

Rapeseed cake contains a considerable amount of protein, rich in sulphur amino acids, and, because of its higher crude fat level and lower fibre content, RC is a richer source of metabolizable energy for monogastric animals as compared to solvent-extracted rapeseed meal. The content of anti-nutritive factors, such as glucosinolate and erucic acid, in rapeseed, has been reduced during the last 20 years by plant breeding programmes, so the risk in the use of rapeseed products as animal feed has too been reduced. The results of previous experiments have demonstrated that RC can be used as a feed component in the diets of broiler chickens (Suchy et al. 2002, Peter and Dänicke 2003, Smulikowska et al. 2006), pigs (Schöne et al. 1997, Schöne et al. 2002) and ruminants (Göpfert et al. 2006). The effects of untreated or extruded rapeseed and extracted rapeseed meal on performance indices and egg quality in layers have been studied (Kamińska 2003, Lichovnikova and Zeman 2004, Lichovnikova et al. 2008), but data on the use of rapeseed expeller cake as a feed component for hens are very limited.

The aim of the present study conducted on laying hens was to evaluate the effect of the dietary level of rapeseed expeller cake on egg performance, egg quality, retention and excretion of nitrogen, calcium and phosphorus, and metabolizability of energy.

Material and Methods

Birds and experimental diets

A total of seventy-two, 18-wk-old, Bovans Brown hens, obtained from a commercial source, were placed in the poultry house, in individual cages, on a wire-mesh floor, and under controlled climate conditions. The cage dimensions were 40cm × 40cm × 45cm, equating to 1600 cm^2 total floor space. During the pre-experimental period (up to 28 wks of age), a commercial laying hen diet (17% crude protein, 11.6 MJ/kg nitrogen-corrected apparent metabolizable energy (AME_N), 3.70% calcium and 0.38% available phosphorus) was offered ad libitum.

At 28 wks of age, the hens were randomly assigned one of four treatments, each comprising 18, individually caged layers. During the experiment, the hens had free access to feed and water, and were exposed to a lighting schedule of 14 h of light and 10 h of darkness, with a ligh intensity of 10 lux. The Local Krakow Ethics Committee for Experiments with Animals approved all the experimental procedures relating to the use of live animals.

The rapeseed expeller cake sample (Table 1) used in this study was obtained from a commercial biodiesel production facility (GES Inc., Bidziny, Poland). The cakes were produced from winter

Table 1. Chemical composition of rapeseed expeller cakes used in experiment (g/kg, 'as is' basis)

Item	
Dry matter	913
Crude protein	293
Crude fat	174
Crude fibre	108
Nitrogen free extract	337
Calcium	6.28
Phosphorus	9.68
Methionine	8.41
Lysine	19.1
Cystine	7.25
Threonine	13.8
Tryptophan	3.44
Arginine	16.3
Valine	14.6
Isoleucine	10.1
Leucine	20.0
Phenyloalanine	11.6
Tyrosine	9.28
Histidine	7.93
Aspartic acid	22.8
Serine	13.8
Proline	18.9

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double zero rapeseed of unknown cultivar and contained 23.6 µmol total glucosinolates per kg of dry matter, consisting of (µmol/kg DM) 7.5 progoitrin, 2.8 gluconapin, 1.4 glucobrassicanapin, 0.91 gluconapoliferin, 4.8 4-hydroxyglucobrassicin, 1.0 glucobrassicin and lower amounts of further glucosinolates (as analysed in the laboratory of the National Research Institute of Animal Production in Balice, using the HPLC, according to ISO 9167-1, 1992). During the production process, rapeseeds were heated to 50º C and pressed in a screw press (Alimentarmash, Kishinev, Moldova).

Experimental isonitrogenous and isocaloric corn-soybean diets were formulated to meet or exceed nutrient recommendations (NRC 1994) and contained 0, 4, 6 or 8% rapeseed expeller cake (Table 2).

Chemical analysis

The experimental diets were fed from 28 to 53 wks of age. The nutrient content of the diets was calculated according to the chemical composition

Table 2. Composition and nutrient content of experimental diets (%)

Item	Control	Rapeseed expeller cake (%)		
		4	6	8
Corn	35.50	35.50	35.50	35.50
Wheat	25.65	23.96	23.26	22.57
Soybean meal	23.00	20.70	19.40	18.10
Grass meal	2.00	2.00	2.00	2.00
Rapeseed expeller cake	-	4.00	6.00	8.00
Rapeseed oil	2.50	2.50	2.50	2.50
Limestone	8.80	8.80	8.80	8.80
Dicalcium phosphate	1.65	1.65	1.65	1.65
NaCl	0.30	0.30	0.30	0.30
DL-Methionine (99%)	0.10	0.09	0.09	0.08
Vitamin-mineral premix[1]	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Composition (on as-is basis)				
Calculated values:				
Metabolizable energy[2], MJ/kg	11.6	11.6	11.6	11.6
Crude protein	17.0	17.0	17.0	17.0
Lys	0.815	0.815	0.811	0.808
Met	0.363	0.362	0.365	0.360
Ca	3.66	3.67	3.70	3.72
Total P	0.60	0.64	0.67	0.72
Available P	0.37	0.37	0.37	0.37
Analyzed values:				
Crude protein	17.9	17.8	17.5	17.6
Ca	3.55	3.55	3.50	3.46
Total P	0.66	0.69	0.71	0.72

[1]The premix provided, per 1 kg of diet: vitamin A, 10,000 IU; vitamin D3, 3,000 IU; vitamin E, 50 IU; vitamin K3, 2 mg; vitamin B1, 1 mg; vitamin B2, 4 mg; vitamin B6, 1.5 mg; vitamin B12, 0.01 mg; Ca-pantotenate, 8 mg; niacin, 25 mg; folic acid, 0.5 mg; choline chloride, 250 mg; manganese, 100 mg; zinc, 50 mg; iron, 50 mg; copper, 8 mg; iodine, 0.8 mg; selenium, 0.2 mg, cobalt, 0.2 mg.

[2]Calculated according to European Table (Janssen, 1989) as a sum of the ME content of components.

of raw feedstuffs, and metabolizable energy value, with the accordance the equations from the European Tables (Janssen 1989). The ingredients were analyzed, using standard methods (AOAC 1990), for moisture (method 930.15), crude protein (984.13), crude fat (920.39) and ash (942.05). Amino acids were analyzed in acid hydrolysates, after initial performic acid oxidation of sulfur amino acids and after alkaline hydrolysis of tryptophan (AOAC 1990; method 982.30). Calcium content was analyzed by flame atomic absorption spectrophotometry (AOAC 1990; method 968.08) and total phosphorus content colorimetrically, by the molybdo-vanadate method (AOAC 1990; method 965.17). For the balance study, nitrogen content in the diets and excreta was analyzed using the Kjeldahl procedure (AOAC 1990; method 984.13), gross energy, using an adiabatic bomb calorimeter, total phosphorus content colorimetrically, by the molybdo-vanadate method (AOAC 1990; method 965.17) and calcium content by flame atomic absorption spectrophotometry (AOAC 1990; method 968.08).

Measurements

During the experiment, the number and weight of eggs were registered daily, feed consumption was recorded monthly, and laying rate, daily egg production, daily feed intake and feed conversion (g of feed consumed per 1g of produced eggs) were calculated.

At 48 wks of age, one egg was collected from each hen (18 eggs from each treatment) in order to determine egg quality indices, i.e. albumen height, Haugh Units, yolk color, eggshell thickness and eggshell density. The eggs were analyzed using semi-automated egg quality equipment (QCM+, Technical Services and Supplies (TSS), York, UK). The eggs were weighed, cracked, and the albumen height was measured with an electronic gauge (QCH device, TSS, York, UK). The albumen height was converted to Haugh units using the HU formula (Eisen et al. 1962) by Eggware software (TSS, York, UK). Yolk color was measured using an electronic colorimeter (QCC device, TSS, York, UK) and expressed in Roche scale points. Shell thickness was measured near the equator of the egg using an electronic micrometer (QCT device, TSS, York, UK). Eggshell density (the dried shell weight per unit of shell area, mg/cm^2) was calculated by Eggware software (TSS, York, UK).

An additional 18 eggs from each treatment were collected for measurements of eggshell breaking strength, using an Instron Testing Machine, Model 5542 (Instron Ltd., High Wycombe, England), equipped with a 500 Newton load cell. The eggs were compressed at a constant crosshead speed of 10 mm/min and the breaking strength was determined at the moment of eggshell fracture. At the end of the experiment (53 weeks of age), one egg from each layer was collected for determination of sensory parameters. After boiling for 10 min, the eggs were evaluated by a 6-person panel. The panelists ranked the flavour and taste of the eggs on a 4-point scale (from 2 to 5) for the degree of liking (2 – flavour and taste unacceptable, 3 – acceptable, 4 – good, 5 – very good).

At 38 wks of age, five hens from each treatment were placed into individual balance cages (the cage dimensions were 35cm × 42cm × 45cm, equating to 1470 cm^2 total floor space). After a one-week adaptation period, a total collection of excreta was carried out over 5 days, and feed consumption for each hen was recorded. The excreta were stored in plastic bags at -20ºC for two weeks and, after thawing, were dried in an oven at 50 ºC to a constant weight, then weighed and finely ground. Nitrogen (calcium, phosphorus) retention (mg) was calculated as: nitrogen intake – nitrogen excretion. Nitrogen (calcium, phosphorus) retention as % of nitrogen (calcium, phosphorus) intake was calculated as: nitrogen intake – (nitrogen intake – nitrogen excretion) / nitrogen intake × 100. Dietary apparent AME_N, was calculated by the following formula: AME_N = [gross energy intake – gross energy excretion] – [(nitrogen intake - nitrogen excretion) × 8.73] / feed intake, where 8.73 is the nitrogen correction factor (Titus et al. 1959). Energy utilization in the diets with different levels of RC was calculated as % of AME_N in the gross energy of the diets.

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Statistical Analysis

All data were subjected to statistical analysis using one-way ANOVA. When significant differences in treatment means were detected by ANOVA (F-test), Duncan's multiple range test was applied to separate means. Differences were considered significant at $p < 0.05$. All statistical analyses were performed with Statistica 5.0 PL software (Statsoft, Inc.).

Results and Discussion

The chemical composition of the rapeseed expeller cake being studied (Table 1) was similar to the composition of other RCs obtained using the same technique and previously reported by Schöne et al. (1997, 2002) and Smulikowska et al. (2006). The mean laying rate, across all dietary treatments, and the entire experimental period (between 28–53 wks of hen age) was 94.6%; egg weight, 59.6 g; daily egg production, 56.4 g/hen; daily feed consumption, 116 g/hen and feed conversion per 1 g of eggs, 2.06 g (Table 3). The inclusion of 4, 6 or 8% RC had no significant effect on egg performance parameters in comparison with the hens fed the control diet ($p > 0.05$). The results of the present study were similar to those reported by Obadalek et al. (1997), who found, in an experiment with Hisex Brown hens, that egg production and egg weight were not affected when 3, 6 or 9 % RC was incorporated into the diet. Horniakova and Sojkova (1996) reported that the replacement of soybean meal in the diets of layers with RC at up to 18.5 % had no negative effect on laying performance, but when RC was substituted for soybean meal at 55 or 100%, a reduction in performance was observed. In fattened pigs, 7.5% RC had no effect on performance, but a higher dietary level of RC (15 %) negatively affected feed intake and body weight gain (Schöne et al. 1997, Schöne et al. 2002).

The inclusion level of RC had no effect on egg quality parameters. i. e. albumen height, Haugh units, yolk color and egg shell thickness, density and breaking strength (Table 3). Similarly, Obadalek et al. (1997) found no effect of the dietary level of RC (3, 6 or 9 %), except for moderate yolk depigmentation at the highest level of RC.

Table 3. Effect of dietary level of rapeseed expeller cake on egg performance and egg quality

Item	Dietary rapeseed expeller cake (%)				SEM
	0	4	6	8	
Laying rate, %	94.5	94.2	94.9	94.8	0.45
Egg weight, g	59.3	59.0	60.3	59.8	0.30
Daily egg production, g per hen	56.0	55.6	57.2	56.7	0.51
Daily feed consumption, g per hen	115	116	117	115	0.54
Feed conversion, g of feed per 1g of eggs	2.06	2.09	2.05	2.03	0.02
Albumen height, mm	6.31	6.57	6.02	6.44	0.12
Haugh units	78.3	80.9	76.9	77.4	0.97
Yolk color, Roche scale points	3.67	3.67	3.67	3.58	0.76
Eggshell thickness, µm	382	395	406	400	4.42
Eggshell density, mg/cm^2	92.7	92.6	93.4	98.4	1.23
Eggshell breaking strength, N	33.1	34.3	33.4	34.8	1.12
Flavour of boiled eggs, points	4.10a	4.06a	4.07a	3.67b	0.03
Taste of boiled eggs, points	4.15	4.10	4.07	3.96	0.03

[a, b] – means in rows with different letters differ significantly at $p \leq 0.05$

Table 4. Effect of dietary level of rapeseed expeller cake on N, Ca and P balance and on metabolizability of dietary energy

Item	Dietary rapeseed expeller cake (%)				SEM
	0	4	6	8	
N excretion, mg/hen per day	2007	2022	1973	2045	41.6
N retention, mg/hen per day	1462	1539	1332	1407	35.9
N retained, % of N intake	42.1	43.2	40.2	40.9	0.73
Ca excretion, mg/hen per day	1489[a]	1575[a]	1685[ab]	1907[b]	55.7
Ca retention, mg/hen per day	2353[a]	2396[a]	2105[ab]	1885[b]	65.3
Ca retained, % of Ca intake	61.2[a]	60.3[a]	55.5[ab]	49.8[b]	1.31
P excretion, mg/hen per day	573	614	615	665	14.1
P retention, mg/hen per day	172[a]	156[a]	145[ab]	110[b]	8.24
P retained, % of P intake	23.0[a]	20.3[ab]	19.1[ab]	14.2[b]	1.07
Metabolizability of energy, % of AME_N in the gross energy of the diet	68.7	67.0	66.8	67.5	0.36

[a, b] - means in rows with different letters differ significantly at $p \leq 0.05$

In our study, a 4 or 6 % inclusion level of RC had no effect on the flavour and taste of boiled eggs; however the highest dietary level of RC (8%) negatively affected the eggs' sensory properties (Table 3). A similar effect was reported by Lichovnikova et al. (2008), who used experimental diets containing 8 or 10 % untreated rapeseed. The worsening of eggs' sensoric properties can be linked to the presence of trimethylamine in the yolks when a high level of rapeseed products is used in the diet. It is well known that some brown layers may have a deficiency of oxidase trimethyloamine, an enzyme which converts trimethylamine to odourless products (Butler and Fenwick 1984). The negative effect of rapeseed cake (15% of the diet) on the sensory characteristics of animal origin products (meat) was also observed in pigs (Schöne et al. 2002).

During the balance study, the mean laying rate, across all dietary treatments, was 91.9%; egg weight, 60.1 g; daily egg production, 54.9 g/hen; daily feed consumption, 116 g/hen and feed conversion per 1 g of eggs, 2.11 g; these values did not vary between treatments ($p > 0.05$). The results of the balance study showed no significant effect of the RC dietary inclusion level on the retention and excretion of nitrogen or the percentage of AME_N in the gross energy in the diet (Table 4). In diets with 0, 4, 6 and 8% RC, N balances and metabolizability of energy behaved similarly ($p > 0.05$). For comparison, in an experiment with broiler chickens, Smulikowska et al. (2006) found the relative N retention (as % of N intake) to be 44.7%, and content of AME_N in gross energy of rapeseed cake to be 55.1% (Smulikowska et al. 2006).

The dietary treatment was found to have a significant effect on Ca and P balances (Table 4). The introduction of 8% RC to the diet negatively affected the utilization of these minerals. In hens fed a diet with 8% RC, excretion of Ca and P was higher, and retentions were lower as compared with other experimental treatments ($p \leq 0.05$). Based on the data in the literature, it may be stated that the main reason for the reduced availability of minerals in rapeseed is the high content of phytate in this plant (Nwokolo and Bragg 1977, Fenwick 1982, Żyła and Koreleski 1993). About two-thirds of the phosphorus in rapeseed is bound to phytate and is unavailable for poultry (Nelson 1976). Our results correspond with data from an experiment with layers, where the addition of phytase to a diet with a high level of rapeseed meal (15 %), significantly improved calcium and phosphorus availability (Sasyte et al. 2006). Similar results were obtained in a study with broilers fed a diet with 15% rapeseed meal, using mineralization of the tibia bone as an indicator of phosphorus utilization (Żyła and Koreleski 1993). As compared to

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control group, the significantly higher excretion of P in layers fed with 8% of rapeseed expeller cake has obvious environmental implications in relation to the pollution potential of hen's excreta. Since Um and Paik (1999) have shown that addition of phytase to a low P layer's diet containing rapeseed meal reduced P excretion by as much as 41%, it seems that the use of this enzyme could prove to be an efficient way of improving the P availability in poultry diets containing rapeseed by-products. Addition of phytase, simultaneously with acid phosphatase, pectinase and citric acid, to a diet for broiler chickens, reduced the amount of P excreted by 56% (Żyła et al. 2001).

In conclusion, the results of this study have demonstrated that rapeseed cake produced from double zero cultivars may be incorporated to a level of 6% in the diet of laying hens with no detrimental effect on egg performance and egg quality. Higher levels of RC (8%) may negatively affect the utilization of calcium and phosphorus and the sensoric properties of boiled eggs.

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