THE APPLICATION OF EXTRUDED FULL-FAT RAPESEED IN ISA BROWN LAYING HENS' DIETS

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Abstract. The objective of this work was to analyse the effect of extruded rapeseed on the productivity parameters of laying hens and the internal and external quality of eggs. The experiment was carried out with 36 Isa Brown hens, from 27 to 34 weeks of age. The laying hens of experimental groups were fed diets (as analysed: 17.87% crude protein, 11.37 MJ/kg metabolisable energy, 0.81% lysine, 0.29% methionine, 3.44% calcium and 0.40% available phosphorus), containing 3.5% of extruded rapeseed in the ERS group and 4.5% in the HERS group. Rapeseed was extruded together with faba bean because of technical fulfilment. Due to the extrusion process, the glucosinolate content was reduced by 7.83 µmol/g of rapeseed. During the experimental period, the 4.5% extruded rapeseed had significant effects on egg performance, such as laying intensity, egg production and egg quality parameters, i.e. yolk colour intensity and egg shell thickness. The results of the trial confirmed that extruded full fat rapeseed to 4.5% is suitable to replace soya bean in the compound feed of laying hens.

Keywords: extruded full-fat rapeseed, laying hens, productivity, egg quality

Introduction

The content of nutrient in rapeseed (approximately 40% of oil and 22% of protein) makes it a suitable ingredient for high nutrient dense diets (Lichovnikova et al., 2004; Szymesczko et al., 2010). Rapeseed protein has a physiologically suitable amino acid composition, including high content of essential amino acids like threonine, tryptophan and sulphur containing amino acids (Pastuszewska, 1992). Moreover, its oil is rich in unsaturated fatty acids like omega-3 fatty acids, which are currently of interest in animal nutrition because of possible health promoting effects (Smulikowska et al., 2005; Kamran et al., 2009). Therefore, by definition, rapeseeds that contain low levels of erucic acid (< 2%) in oil and glucosinolates (< 30 µmol/g) in defatted meal are called double-zero or double-low rapeseeds or 00-rapeseeds in Europe (Newkirk, 2009; Spragg and Mailer, 2011). Although content of anti-nutrition factors such as glucosinolates in rapeseed has been markedly reduced through genetic selection, at feeding higher levels of rapeseed can still reduce productivity parameters in animal diets.

Extrusion is one of the methods to reduce the gucosinolate contents (Fenwick et al., 1986; Dänicke et al., 1998). Fenwick et al. (1986) used dry extrusion at temperature 150ºC and 130ºC, and Dänicke et al. (1998) used hydrothermal treatment at 105ºC. Full-fat canola, after heat treatment and particle size reduction, is a mainstay protein and energy ingredient in broiler feeds in some countries like Denmark (Canola Council of Canada, 2009). Liang et al. (2002) also reported about a positive effect of extrusion on the feeding value of rapeseed meal. However, rapeseed meal has a little different quality than raw rapeseed because of its treatment after oil extraction. A previous experiment with extruded rapeseed cake, conducted by Świątkiewicz with colleagues (2010), has demonstrated that rapeseed expeller cake may be incorporated in laying hens' diets to a level of 6% with no detrimental effect on egg performance and egg quality. Lichovnikova with colleagues (2000) conducted an experiment with laying hens, in which diets contained extruded rapeseed, wheat, and peas at a ratio of 3 : 4 : 3. There were 45% of this combination feed in the mixtures. The results of their conducted experiment did not show a significant effect on the productivity parameters and egg quality of laying hens. Similar results were obtained by Ciurescu (2009) in the experiment with commercial layers fed with diets in which 20% of canola seeds were replaced with dietary soya bean meal. In both experiments, the reason of insignificant results could be the high level of rapeseed and canola seeds in the diets.

Therefore, the objective of this study was to investigate the effects of dry extrusion processing on partial reduction in total glucosinolate content of locally produced rapeseed and on productivity and egg quality parameters of laying hens. Rapeseed was extruded together with faba beans because of technical fulfilment.

Material and methods

A total of 64, 25-week-old Isa Brown hens, obtained from a commercial source, were placed in a poultry house, in individual cages, on a wire-mesh floor, and under controlled climate conditions. The cage dimensions were 0.40 m x 0.40 m x 0.44 m. During the pre-experimental periods (up to 27 weeks of age), a commercial laying hen diet (17.25% crude protein, 11.37 MJ/kg metabolisable energy, 3.44% calcium and 0.40% available phosphorus) was offered at 125 g per day.

At 27 weeks of age, the hens were according to weight randomly assigned to 1 of 3 treatments (CONTR, ERS and HERS), each comprising 12 individual caged layers. During the test, the hens had free access to feed and water and were exposed to the lighting schedule of 14 hours of light and 10 hours of darkness, with a light intensity of 10 lux.

The trial with laying hens was conducted following the regulations of the Republic of Lithuania (01-01-2013 new edit of 06-11-1997) for animal welfare and handling (Valstybės žinios, 2012, No. 122-6126) and by the State Food and Veterinary Service of the Republic of Lithuania Director order regarding animals used for experiments, research, storage, maintenance and operating requirements (24-09-2015, No. B1-872 change by order 31-10-2012, No. B1-866). The trial was performed in accordance with EU Directive 2010/63/EEC and the EC recommendation 2007/526 EC for Animal use and storage for experiments and other purposes.

The main composition of the diets was the same, but extruded soya bean seeds were replaced with 5% of the mixture, composed of 70% of rapeseed and 30% of faba bean in the ERS group (rapeseed composed 3.5%) and 6.45% in the HERS group (rapeseed composed 4.5%). Rapeseed and faba bean were separately extruded and then ground and mixed together. The extruder was made by Insta-Pro International the model Insta-Pro 2 500 (USA). The extruded meals were mixed with the rest of components. The chemical composition and extruded parameters of full-fat rapeseed, used in the experiment with laying hens, are shown in Table 1. Rapeseed with low content of glucosinolates (so called double zeros ‘00’) was used. For the glucosinolate content, the samples of non-treated rapeseed and extruded rapeseed were analysed, and it was determined that glucosinolates composed 14.7 µmol/g and 6.87 µmol/g, respectively. The total glucosinolate content was analysed in an independent accredited laboratory Labtarna (Lithuania). The birds were fed for 8 weeks, 125 g per day. A corn–wheat experimental diet was formulated to meet the nutrient and energy requirement for laying hens (NRC, 1994) (Table 2). The content of moisture, crude protein, crude fat, crude fibre, crude ash, starch, calcium and phosphorus was determined with near infra-red reflectance spectroscopy (NIRS) analysis. The diets and rapeseed samples reflectance spectra were measured by means of NIRS using a Foss − Tecator equipment DS2500 on milled grain samples. NIRS calibration models for the content of analysed parameters were developed using software ISIscan Nova (Germany).

Table 1. **Quality parameters of full-fat rapeseed used in the experiment with laying hens**

Parameters	Rapeseed	Rapeseed (grinding with faba bean)
Dry matter before extrusion process, %	92.5	-
Dry matter after extrusion process, %	94.2	-
The moisture during extrusion,%	12-18	-
Exposition time, s	16	-
Dry matter, %	-	91.40
Crude protein, %	23.3	27.23
Crude fat, %	40.5	29.00
Crude fibre %	5.0	8.81
Crude ash, %	5.0	6.81
Starch, %	1.0	7.89
Extrusion temperature ºC	105-108	-
Colour	Dark	-

During the study, all the eggs were calculated and weighed daily, and every 14 days egg production capacity of laying hens and feed conversion ratio to produce 1 kg of eggs were determined. Egg weight, albumen high, Haugh unit and yolk colour intensity were established by multifunctional automatic egg characteristics analyser Robotmation (Japan) Egg Multi–Tester EMT–5200, pH of eggs albumen and yolk by Inolab 730 equipment (determination ranges between pH 2 and pH 10±0.5), hardness of eggshell by Egg Shell Force Gauge MODEL–II device, and thickness of eggshell by electronic micrometer MITUTOYO Digimatic Micrometer (sharp and, blunt end, and equator).

The colour of egg yolk was determined instrumentally by Minolta Chroma-meter (CR-410, Konica Minolta, Osaka, Japan) in the CIE L* a* b* space. The L* value indicates the lightness, representing dark to light (0–100). The a* (redness) value gives the degree of the red–green colour, with a higher positive a* value indicating more red colour. The b* (yellowness) value indicates the degree of the yellow–blue colour, with a higher positive b* value indicating more yellow colour. White calibration with the specifications of Y=86.2, x=0.3160 and y=0.3231 was used to standardise the chroma meter.

The egg shell index was calculated according to Ahmed et al. (2005) as: SI (shell index) = (SW/S) × 100 where: SW = shell weight; S = shell surface calculated as $S = 4.68 \times \text{egg weight } (EW)^{2/3}$

Statistical analysis. Statistical significance was established using one–way analysis of variance (ANOVA), and the data were reported as a mean of standard deviation. Mean comparison and separation were done using the Duncan *t* test ($P < 0.05$). ANOVA was conducted using the statistical package SPSS 22.

Table 2. **Chemical composition, calculated and analysed values of the diet used in the experiment with laying hens (%)**

Ingredients	Groups		
	CONTR	ERS	HERS
Wheat	22.78	21.78	20.78
Corn	20.00	20.00	20.00
Soya bean meal	15.76	15.76	15.31
Triticale	12.00	12.00	12.00
Sunflower seed meal	8.00	8.00	8.00
Limestone	9.04	9.04	9.04
Extruded soya bean	4.00	-	-
Faba beans	3.00	3.00	3.00
Oil	3.24	3.24	3.24
Monocalcium phosphate	0.87	0.87	0.87
Starch	0.40	0.40	0.40
Salt	0.29	0.29	0.29
Methionine hydroxy analogue	0.17	0.17	0.17
Wheat meal	0.14	0.14	0.14
Organic acids	0.10	0.10	0.10
Mineral–vitamin mixture**	0.21	0.21	0.21
Extruded rapeseed	-	5.00	6.45
Calculated values, %			
ME (metabolized energy), MJ/kg	11.37	11.37	11.38
Dry matter*	89.71	89.83	89.86
Crude protein*	17.87	18.24	17.92
Crude fat*	6.13	7.58	7.75
Crude fibre*	3,65	3.97	4.27
Crude ash*	10.78	10.45	10.74
Starch*	38.83	36.19	36.51
Sugar	3.01	3.00	3.00
Lysine	0.81	0.81	0.81
Methionine	0.29	0.30	0.30
Methionine + cystine	0.62	0.62	0.62
Calcium (Ca)*	3.44	3.44	3.44
Phosphorus (P)*	0.63	0.63	0.63
Phosphorus (av.)	0.40	0.40	0.41

*Analysed values

** Mineral–vitamin mixture was composed of 1 kg of feed: vit. A – 11.000 IU, vit. D_3 – 5.000 IU, vit. E – 40 mg, vit. K_3 – 2.50 mg, vit. B_1 – 2.50 mg, vit. B_2 – 7.00 mg, vit. B_6 – 4.00 mg, vit. B_{12} – 25.00 µg, Nicotinic acid – 55.00 mg, pantothenic acid– 15.00 mg, folic acid – 1.75 mg, biotine – 100.00 µg, cholin chloride – 400.00 mg, choline – 400.00 mg, Fe - 70.00 mg, Mn – 93.75 mg, Zn – 60.00 mg, Cu – 6.00 mg, I – 0.50 mg, Se – 0.20 mg, Co – 0.10 mg

Results and discussion

The inclusion of 4.5% of extruded rapeseed (HERS group) (Table 3) increased the average feed intake at 27–28 weeks of age by 3% compared with the CONTR group ($P < 0.05$), and this tendency for higher feed intake remained from 31 to 34 weeks of age; meanwhile, in the ERS group, a higher average feed intake was observed only at 31 and 32 weeks of age. The positive effect of 4.5% of extruded rapeseed on feed conversion ratio to produce 1 kg of eggs was observed only at the end of the experiment (33-34 weeks), but during the entire experimental period there was no observed statistical effect on the analysed parameter.

By analysing the effect of extruded rapeseed on egg mass, the statistical differences between treatments were not determined. For other laying hens' productivity characteristics, such as laying intensity and egg production, the higher inclusion of extruded rapeseed had a positive effect, and laying intensity from 29 to 34 weeks of age increased from 5% to 10% ($P<0.05$), and during the entire experimental period was by 5% higher ($P<0.05$) in comparison with the CONTR group without rapeseed inclusion. Egg production parameters were statistically different only for HERS group during the entire experimental period. Jeroch et al. (2005) registered only a slight decline in feed consumption because of the treatment.

Lichovnikova with colleagues (2000) reported that the replacement of soya bean meal in diets of layers with extruded rapeseed at up to 13.5% had no effect on laying performance. Another experiment conducted by Angelovičová and Angelovič (2013) with 288 Shaver

Starcross laying hens from 22 to 42 weeks of age showed no statistical effect on the hens' productivity parameters (feed consumption, egg weight and laying intensity), when 5% of rapeseed cake was incorporated into the diet.

One of the reasons of better performance of laying hens in our study could be the suggestion that grinding was used in this experiment. In general, grinding is used to disrupt the cell wall structure of feed ingredients and oil body structure within oilseeds, thus, increasing the exposure of nutrients to digestive enzymes, which is believed to positively impact the bird performance (Meng et al., 2006; Assadi et al., 2011).

Table 3. **Effect of 3.5% and 4.5% of full-fat extruded rapeseed on the laying hens' performance**

Parameter	Laying hens' age (week)	Groups		
		CONTR	ERS	HERS
Average feed intake (g/hen/14 day)	27-28	1490±16.31^{a}	1488±33.00^{ab}	1542±17.33^{b}
	29-30	1723±13.06	1712±23.90	1703±17.40
	31-32	1519±9.68^{a}	1702±36.29^{b}	1714±18.55^{bc}
	33-34	1526±10.47^{a}	1492±52.62^{ab}	1571±15.69^{b}
	27-34	**6257 ± 14.69^{a}**	**6394 ± 23.64^{b}**	**6529.17 ± 13.17^{bc}**
Feed conversion ratio to produce 1 kg of eggs (kg/kg)	27-28	1.92±0.12	2.04±0.18	2.12±0.21
	29-30	2.33±0.08	2.15±0.12	2.04±0.05
	31-32	2.24±0.09	2.24±0.17	2.16±0.04
	33-34	2.26±0.09^{a}	2.07±0.10^{ab}	1.99±0.03^{b}
	27-34	**2.19±0.27**	**2.13±0.11**	**2.08±0.05**
Egg-mass (g/hen/day)	27-28	62.37±1.37	62.37±1.00	61.59±1.15
	29-30	63.65±1.36	62.80±1.09	62.20±0.77
	31-32	61.17±1.00	60.10±1.10	59.31±0.70
	33-34	66.63±1.21	65.46±1.15	64.19±0.99
	27-34	**63.45±0.65**	**62.68±0.58**	**61.82±0.50**
Laying intensity (%)	27-28	91.67±3.65	88.10±5.30	89.29±4.82
	29-30	91.07±4.87^{a}	92.86±3.79^{ab}	96.43±1.45^{b}
	31-32	89.29±6.19^{a}	92.86±5.51^{ab}	96.43±1.13^{b}
	33-34	85.12±6.05^{a}	85.12±7.08^{ab}	95.24±1.40^{b}
	27-34	**89.29±2.48^{a}**	**89.73±2.61^{ab}**	**94.35±1.31^{b}**
Egg production (eggs/14 day/group)	27-28	13±0.51	12±0.74	13±0.67
	29-30	13±0.68	13±0.53	14±0.20
	31-32	13±0.87	13±0.77	14±0.16
	33-34	12±0.85	12±0.99	13±0.20
	27-34	**50±0.35^{a}**	**50±0.37^{ab}**	**53±0.18^{b}**
a, b, c For each row, mean values with the same subscripts are not significantly different, P < 0.05				

Table 4 indicates the internal egg quality traits. The dietary treatments did not affect egg weight, albumen height, albumen and yolk pH. However, the Haugh units at 34 weeks of age improved ($P < 0.05$) with 3.5% of full-fat extruded rapeseed, and the difference between CONTR (75.05%) and ERS groups (88.09%) was significant ($P < 0.05$). The Haugh unit results from the entire experimental period demonstrated that there were statistical differences between the HERS and the CONTR groups. The results of the present study were similar to those reported by Jeroch et al. (1999) who did not observe a higher weight of eggs in different groups fed the expeller treated rapeseed.

At the beginning of the experiment, the lower albumen weight and the higher yolk weight were determined in the HERS group in comparison with the CONTR group. Yolk colour intensity in the groups with extruded rapeseed supplementation increased from week 30, but significant differences were determined from 32 weeks of hens' age. The yolk colour evaluation according to lightness (L), redness (a) and yellowness (b) showed that with the higher level of extruded rapeseed in the diets there were lower L and higher b values. Similarly, Obadalek et al. (1997) found no effect of the dietary level of rapeseed cake (3%, 6% or 9%), except for moderate yolk depigmentation at the highest level of rapeseed cake.

The inclusion of full-fat extruded rapeseed had no effect on egg shell quality parameters, i.e. shell breaking strength, shell weight with and without coat and shell index. Only the shell thickness was significantly affected by feeding rapeseed ($P < 0.05$). In this regard, comparisons between treatment means during the entire experimental period showed that the CONTR group had the highest values, while hens fed diet containing 4.5% of extruded rapeseed produced eggs with a thinner shell. Similarly, Świątkiewicz et al. (2010) found no statistically significant effect of the dietary level of rapeseed cake (4, 6, or 8%) on the egg shell quality parameters. Lichovnikova et al. (2000) reported that the replacement of soya bean meal in the diets of layers with extruded rapeseed by 13.5% had no effect on the strength and thickness of the egg shell.

Table 4. **Effect of 3.5% and 4.5% of full-fat extruded rapeseed on the laying hens' internal egg quality**

Studied character	Laying hens' age (week)	Group		
		CONTR	ERS	HERS
Egg weight (g)	28	61.98±2.02	61.73±1.27	60.25±0.89
	30	64.95±1.65	64.12±1.36	63.26±1.27
	32	64.48±1.28	63.93±1.46	60.09±2.49
	34	64.36±1.30	63.51±1.94	63.27±1.40
	28-34	**63.94±0.77**	**63.26±0.63**	**61.72±1.03**
Albumen height (mm)	28	7.97±0.51	7.11±0.42	7.10±0.32
	30	7.53±0.38	7.24±0.33	7.86±0.36
	32	6.34±0.89	7.34±0.69	7.63±0.64
	34	6.63±0.63	7.88±0.45	6.86±0.32
	28-34	**7.12±0.44**	**7.39±0.19**	**7.29±0.33**
Haugh units	28	88.07±3.06	82.04±3.12	82.18±1.95
	30	81.59±2.53	77.53±2.94	86.18±2.67
	32	70.13±7.09	81.63±5.25	85.38±4.25
	34	75.05±5.77^{s}	88.09±2.57^{b}	79.19±2.53^{ab}
	28-34	**78.71±4.51^{a}**	**82.32±2.51^{ab}**	**83.23±1.85^{b}**
Albumin weight (g)	28	39.29±1.49^{a}	37.80±1.13^{ab}	35.45±0.62^{b}
	30	39.50±1.43	39.44±1.01	39.83±1.81
	32	38.84±1.25	39.53±1.11	35.09±2.48
	34	39.95±1.07	38.43±1.59	37.68±0.73
	29-34	**39.40±0.27**	**38.80±0.48**	**37.01±1.27**
Albumin pH	28	8.20±0.05	8.28±0.04	8.28±0.06
	30	8.33±0.06	8.32±0.05	8.24±0.05
	32	8.24±0.05	8.34±0.02	8.54±0.04
	34	8.16±0.05	8.20±0.04	8.56±0.05
	28-34	**8.23±0.04**	**8.31±0.02**	**8.20±0.11**
Yolk weight (g)	28	14.44±0.47^{a}	16.00±0.68^{ab}	16.61±0.72^{b}
	30	17.53±0.74	17.02±0.54	16.73±0.72
	32	17.51±0.50	16.69±0.48	17.01±0.76
	34	16.45±0.75	17.33±0.59	17.48±0.77
	28-34	**16.48±0.84**	**16.76±0.33**	**16.95±0.22**
Yolk pH	28	6.16±0.05	6.27±0.08	6.33±0.06
	30	6.25±0.06	6.23±0.04	6.19±0.03
	32	6.11±0.04	6.13±0.07	6.21±0.03
	34	6.19±0.07	6.27±0.06	6.24±0.06
	28-34	**6.15±0.04**	**6.22±0.04**	**6.27±0.04**
Yolk colour intensity	28	3.40±0.28	3.20±0.31	3.30±0.22
	30	3.00±0.27	3.56±0.24	3.80±0.37
	32	3.20±0.14^{a}	4.50±0.18^{b}	4.50±0.18^{cb}
	34	3.30±0.32^{a}	4.10±0.25^{b}	4.80±0.26^{cb}
	28-34	**3.23±0.10^{a}**	**3.84±0.33^{ab}**	**4.10±0.39^{b}**
Yolk colour evaluation				
L*	28	68.61±0.40^{a}	70.18±0.78^{ab}	66.81±0.48^{b}
	30	63.31±3.11	65.30±0.49	66.82±0.59
	32	66.74±0.56	67.53±0.39	65.43±0.46
	34	67.48±0.53^{a}	67.72±0.63^{ab}	65.15±0.65^{b}
	28-34	**66.54±1.32**	**67.68±1.15**	**66.05±0.51**
a*	28	-6.23±0.52	-7.11±0.39	-5.63±0.66
	30	-5.32±0.77	-6.46±0.72	-5.34±0.61
	32	-7.18±0.36	-6.82±0.33	-6.58±0.73
	34	-6.10±0.68	-6.85±0.31	-5.84±0.33
	28-34	**-6.21±0.44^{a}**	**-6.81±0.16^{ab}**	**-5.85±0.31^{b}**
b*	28	46.74±1.74	46.19±1.29	48.68±1.16
	30	45.34±1.81	47.69±1.46	48.27±1.25
	32	46.80±1.95	47.45±0.95	48.78±1.13
	34	47.66±0.97	48.33±1.11	47.05±2.05
	28-34	**46.64±0.56^{a}**	**47.42±0.52^{ab}**	**48.20±0.46^{b}**

a, b For each row, mean values with the same subscripts are not significantly different, $P < 0.05$
*L – lightness, a – redness, and b - yellowness

Table 5. **Effect of 3.5% and 4.5% of full-fat extruded rapeseed on the laying hens' egg shell quality**

Analysed character	Laying hens' age (week)	Group		
		CONTR	ERS	HERS
Shell breaking strength (kg/cm^2)	28	4.55±0.48	3.95±0.23	4.25±0.17
	30	3.61±0.26	3.57±0.14	3.78±0.08
	32	3.76±0.22	3.70±0.13	3.77±0.30
	34	3.66±0.19	3.11±0.23	3.65±0.36
	28-34	**3.89±0.25**	**3.59±0.20**	**3.86±0.15**
Shell weight with coat (g)	28	8.26±0.43	7.94±0.18	8.19±0.21
	30	7.92±0.18	7.67±0.14	8.37±.56
	32	8.13±0.27	7.71±0.11	8.00±0.33
	34	7.96±0.28	7.76±0.40	8.12±0.26
	28-34	**8.07±0.09**	**7.77±0.07**	**8.17±0.09**
Shell weight without coat (g)	28	5.95±0.21	5.70±0.18	5.74±0.19
	30	6.05±0.14	5.53±0.14	6.11±0.10
	32	6.01±0.19	5.86±0.19	5.76±0.22
	34	5.65±0.11	5.71±0.22	5.91±0.19
	28-34	**5.91±0.10**	**5.70±0.08**	**5.88±0.10**
Shell thickness (mm)	28	0.44±0.01^{a}	0.39±0.01^{bc}	0.36±0.01^{c}
	30	0.34±0.00^{a}	0.33±0.00^{ab}	0.38±0.01^{b}
	32	0.41±0.01	0.39±0.01	0.38±0.01
	34	0.39±0.01	0.38±0.01	0.39±0.01
	28-34	**0.40±0.00^{a}**	**0.37±0.00^{b}**	**0.38±0.00^{bc}**
Shell index (g/100 cm^2)	28	8.11±0.15	7.80±0.22	7.97±0.25
	30	8.02±0.23	7.39±0.20	8.09±0.09
	32	7.99±0.24	7.83±0.20	8.03±0.22
	34	7.52±0.14	7.66±0.21	7.95±0.19
	28-34	**7.91±0.15**	**7.67±0.12**	**8.01±0.04**
a, b For each row, mean values with the same subscripts are not significantly different, $P < 0.05$				

Conclusions

The results of this study demonstrate that extruded full-fat rapeseed produced from double zero cultivars at a level of 4.5% improved laying hens' productivity parameters, such as laying intensity, egg production, feed conversion ratio and egg quality parameters, i.e. Haugh unit and yolk colour intensity.

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