The quality comparison of eggs laid by laying hens kept in battery cages and in a deep litter system

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ABSTRACT: At present the laying hen rearing is transformed into alternative housing systems which include a deep litter system. As for the poultry nutrition, the replacement of animal protein with vegetable protein in poultry feed is applied. Therefore, in an experiment we evaluated the quality of eggs from laying hens in the cage system as compared to the deep litter system with vegetable protein substituted for animal protein in their feed. 72 ISA Brown laying hens were placed into the experiment. 36 laying hens were kept in the deep litter system and 36 laying hens were kept in conventional cages for laying hens. For the period of 9 months, 36 eggs from the group in the deep litter system were examined, always at intervals of five weeks (i.e. 8 × 36 eggs) and so were 36 eggs from the group in the cage system (i.e. 8 × 36 eggs). We found out that in the deep litter system the mean egg weight was higher ($P < 0.01$), shell weight was lower ($P < 0.01$), egg albumen was higher ($P < 0.01$), yolk weight did not differ ($P > 0.05$), yolk cholesterol was higher ($P < 0.01$), yolk colour was darker ($P < 0.05$), shell strength did not differ ($P > 0.05$), all in comparison with the cage system of laying hen keeping. The results of the experiment show that where vegetable protein was substituted for animal protein in the nutrition of laying hens, there were differences in the quality of eggs from laying hens kept in the deep litter system and eggs from laying hens kept in the cage system.

Keywords: laying hen; rearing technology; egg weight; egg albumen weight; yolk weight; yolk cholesterol; yolk colour; shell strength

At present there are important changes in housing systems in laying hen husbandry. Henceforward, only alternative husbandry systems shall be allowed, among which deep litter systems can be included. Therefore, many authors are engaged in the investigation of alternative systems, their advantages and disadvantages.

Savory (2004) stated that from the welfare viewpoint cage systems were burdened with a lack of space for laying hens, however, conversely they ensured the better health status of laying hens. Petermann (2003) concluded that alternative aviary systems with deep litter were burdened with higher mortality of laying hens. De Boer and Cornelissen (2002) considered battery cages to be more favourable than aviary systems, in particular from the viewpoint of stock economics, ammonia emission, egg quality and farmer welfare. Duncan (2001) analysed advantages and disadvantages of battery cage systems. He considered the low incidence of diseases, low incidence of social frictions, and the absence of problems resulting from litter as the main advantages. The disadvantages were found to be a lack of both physical and psychological space for laying hens, lack of space for daily activities and nesting and dust bathing opportunities, and a higher incidence of foot lesions. Cooper and Albentosa (2003) assessed the advantages and disadvantages of cages systems in a similar way. Furnished cages will be the only legal form of cages in the EU from 2012. Tauson (2002) compared two alternative systems – furnished cages and aviary systems.

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According to this author the furnished cages try to combine advantages of small group size in cages and to reduce disadvantages of poor air condition, and sometimes inferior hygiene, in floor-kept hens. Tauson (2005) stated that developed models of furnished cages provided similar production results to conventional cages, but differences still existed e.g. in egg quality traits between the models. Baxter (1994) emphasized the unsatisfactory welfare of laying hens in conventional cages resulting, in particular, from the insufficient movement in a cage. Appleby and Hughess (1991) stated that no system was ideal from the aspect of production, welfare, layers' health, and mortality. Hetland et al. (2004) compared 2 400 layers in conventional 3-hen cages and two furnished cage systems with 8 or 16 birds. Egg production was lower in furnished cages than in conventional cages. The frequencies of rear body wounds also increased as the group sizes increased. Abrahamsson et al. (1996) studied production, interior and exterior egg quality, health, plumage, keel bone and foot condition in hens that were housed in battery cages with three hens per cage and in two aviary systems with tiered wire floors and litter – Lovsta with two tiers and Marielund with three tiers. They did not observe any effects on egg quality traits.

Nutrition modifications are another developmental trend in laying hen stocks. In connection with the trend of replacing proteins of animal origin in the feed for poultry, substitutions at the level of vegetable products are sought. The substitution of animal protein in the poultry diet with vegetable protein on the basis of lupin (Proenergol preparation) was described by Suchy et al. (2002). Hadorn et al. (2000) and Suchy et al. (2004), who evaluated the differences in metabolic profiles of egg-type and meat-type hybrid hens, dealt with the substitution of animal protein with vegetable protein in laying hens.

Halaj et al. (1998) dealt with egg weight in various breeds of laying hens. They found out that various breeds of laying hens had different egg weights. Keeling et al. (2003) investigated the influence of group sizes of laying hens which were kept together on egg weight. They discovered that egg weight was different in various size groups of laying hens. Jiang and Sim (1991) also dealt with egg and yolk weight. They stated that egg weight and yolk weight expressed as absolute weight and as the proportion in egg weight (%) increased during the first six months of the egg-laying period. Egg weight was one of the parameters monitored by Tumova and Ebeid (2005) when determining the influence of the time of oviposition on egg quality in both types of laying hen housing systems (cages and deep litter systems). Anderson and Adams (1994) measured egg production, egg quality, feed conversion, and mortality over a 48-week production cycle in hens reared in two rearing systems (cages and floor-reared birds). Hens reared in cages produced heavier eggs with a higher percentage of Grade A eggs. Leyendecker et al. (2002) compared the bone strength and eggshell stability of laying hens kept in three housing systems: battery cages, aviary and furnished cages. In all three housing systems the eggshell stability was at the lowest point at the end of laying period. Van den Brand et al. (2004) dealt with yolk colour. They discovered that the yolk colour was darker in the free range rearing of laying hens in comparison with conventional keeping in cages. Nys (2000) stated in connection with the yolk colour that the association of the yolk colour and acceptability of eggs as a food was common and that the darker yolk colour could be preferred by consumers. Simeonova et al. (1992) were engaged in the cholesterol content in quail eggs. They stated that the cholesterol content in eggs was important from the viewpoint of human nutrition. Maurice et al. (1994) studied the cholesterol content in eggs from several breeds of laying hen lines. They found out that the age of laying hens did not influence the cholesterol content in the egg yolk. The effect of the hen age, genotype, rearing system and dietary structure on the egg and serum cholesterol content and some other characteristics of eggs were investigated by Basmacioglu and Ergul (2005) in laying hens. They found positive and significant correlations between egg cholesterol content and egg weight, and yolk weight, and also between serum cholesterol and egg production for each genotype. Ledvinka et al. (2002) studied the shell quality in laying hens. They monitored the shell quality and discovered differences in the shell strength in various laying hen lines.

MATERIAL AND METHODS

The egg quality of laying hens kept in two rearing technologies, a deep litter system and a conventional cage system, was compared. 72 laying hens of ISA-Brown hybrid, divided into two groups consisting of 36 laying hens each, were placed into an experiment. 36 laying hens were kept in the deep litter system – floor pen rearing was used (338 cm^2/hen), 36 laying hens were kept in conventional three floor cages for laying hens with automatic watering using nipple drinkers ad libitum and hand feeding and egg collection. Laying hens were housed in cages individually (418 cm^2/hen). In microclimatic and light conditions of the rearing systems the technological standard for the rearing of this hybrid was observed. Basic microclimatic parameters during the experiment were as follows: air temperature ranged between 13 and 18°C, relative humidity was kept between 70 and 75%, and the length of daylight during the experiment was 16 hours. The administration of N1 and N2 feeds, in which animal protein was replaced by vegetable protein on the basis of lupin, was ad libitum using automatic feeders. The composition of N1 and N2 feeds is shown in Table 1. The formulation of N1 feed mixture was as follows: wheat 25.7%, maize 30.0%, extracted soybean meal 20.3%, soybean oil 3.3%, lupin 10.0%, and other amino acid, vitamin and mineral supplements. The N2 feed mixture contained: wheat 31.5%, maize 35.0%, extracted soybean meal 15.5%, soybean oil 1.5%, lupin 6.0% and other amino acid, vitamin and mineral supplements.

For the period of 9 months, 36 eggs were taken from the laying hen group kept in the deep litter system (i.e. 8 × 36 eggs) and 36 eggs from the laying hen group kept in the conventional cage system (i.e. 8 × 36 eggs), always at a five-week interval. The weight of laid eggs, shell weight, egg albumen weight, yolk weight, yolk cholesterol (photometrically with commercially available Bio-La-Tests kits made by Pliva-Lachema, a.s.), yolk colour and shell strength (shell strength was determined by the kit for destructive measurement of eggs – Vyslouzil, Brno) were monitored. Out of these data, the mean egg weight, mean shell weight (grams and %), mean egg albumen weight (grams and %), mean yolk weight (grams and %), mean cholesterol content in yolk (%), yolk colour (according to the Roche colour scale) and shell strength (in newtons using a device for destructive measurement of egg shell strength) were calculated for each collection and then for all eggs in total.

The results were statistically processed using the statistic program Unistat version 5.1. Mean values obtained from the deep litter group and from the cage group were compared using the unpaired *t*-test.

RESULTS AND DISCUSSION

Replacing restrictive laying hen rearing in cage systems with alternative husbandry systems, in particular deep litter ones, is motivated, above all, by the requirements for the welfare of laying hens. However, the impact of this change on egg production, health and mortality of laying hens is not unambiguous as documented in the stud-

Table 1. Nutrient composition of feed for laying hens

Nutrients	N1 till the layers' age of 32 weeks (g/kg)	N2 from the layers' age of 32 weeks (g/kg)
Crude protein	185.00	161.56
Fat	56.67	39.76
Crude fibre	35.38	31.55
N-free extract	493.67	538.89
Ash	124.14	119.39
ME_N (MJ/kg)	11.70	11.35
Ca	36.01	35.34
P	7.28	6.37
Mg	1.64	1.58
Lysine	8.64	7.58
Methionine	4.31	3.78
Threonine	6.20	5.63
Tryptophan	1.80	3.87
Arginine	13.15	10.65

Table 2. Egg weight (g)

Collection		1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	49.89	60.84	62.73	62.62	65.49	65.82	64.44	64.37	62.02
	sd	3.88	3.81	4.51	3.51	3.62	2.96	3.98	4.21	6.15
Cages	$\bar{x}$	50.46	58.80	60.71	60.81	63.28	63.73	62.14	65.12	60.63
	sd	4.23	4.02	3.96	3.91	5.46	5.42	3.64	4.73	6.15
	P	0.55	0.03*	0.05*	0.04*	0.05*	0.05*	0.01**	0.48	0.01**

$\bar{x}$ = arithmetic mean, sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

ies of Appleby and Hughess (1991), Baxter (1994), Duncan (2001), de Boer and Cornelissen (2002), Cooper and Albentosa (2003), Petermann (2003), Hetland et al. (2004), Savory (2004), Tauson (2002, 2005), and others.

The trend to replace animal proteins in feed for laying hens with vegetable protein brings further changes in laying hen rearing. Results of experiments focused on the replacement of meat-and-bone meal with vegetable feed in broilers were described by Suchy et al. (2002), and in laying hens by Hadorn et al. (2002) and Suchy et al. (2004). It is possible to expect further developments in this field.

In our experiments we thus compared differences in the quality of eggs from laying hens kept in two different technologies, the deep litter system and the cage system, at the same nutrition level, when meat-and-bone meal in poultry feed was replaced with a vegetable component based on the lupin. We observed a lot of differences in egg quality between these two technologies. Abrahamsson et al. (1996) reported no effects on egg quality in their experiments with hens in battery cages and hens in aviary systems.

Mean egg weight was monitored in the deep litter system and in the conventional cage system. The results are shown in Table 2. It follows from the table that the egg weight was statistically highly significantly higher in the deep litter system of laying hen keeping.

Furthermore, shell weight was monitored. The results are shown in Table 3. It follows from the table that the shell weight was higher in eggs from the cage system. In the calculation of the proportion of shell weight in egg weight (%), this difference was statistically significant not only in the total number but also from the third interval of monitoring. Basmacioglu and Ergul (2005) reported that shell weight was not influenced by the rearing system.

Albumen weight was also monitored. The results are given in Table 4. It follows from the table that the egg albumen weight was higher in eggs from the deep litter system and this difference was sta-

Table 3. Shell weight

Collection			1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	(g)	6.10	7.09	7.01	7.32	7.63	7.71	7.66	7.71	7.28
	sd	(g)	0.56	0.92	0.73	0.60	0.49	0.53	0.75	0.81	0.85
Cages	$\bar{x}$	(g)	6.31	6.83	7.36	7.67	7.76	7.86	7.96	8.11	7.48
	sd	(g)	0.79	0.61	0.72	0.58	0.64	0.99	0.69	0.96	0.95
	P		0.21	0.15	0.04*	0.01**	0.36	0.45	0.08	0.06	0.01**
Deep litter	$\bar{x}$	(%)	12.24	11.65	11.16	11.70	11.66	11.72	11.89	11.96	11.75
	sd	(%)	0.80	1.30	0.76	0.84	0.54	0.65	0.97	0.81	0.90
Cages	$\bar{x}$	(%)	12.49	11.62	12.12	12.63	12.28	12.30	12.83	12.45	12.34
	sd	(%)	1.09	0.82	0.82	0.93	0.72	1.10	1.10	1.20	1.03
	P		0.27	0.90	0.00**	0.00**	0.00**	0.01**	0.00**	0.05*	0.00**

$\bar{x}$ = arithmetic mean; sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

Table 4. Egg albumen weight

Collection			1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	(g)	32.18	38.83	39.81	38.94	40.04	40.34	39.01	39.83	38.62
	sd	(g)	3.00	3.23	3.82	2.69	2.63	2.78	3.49	3.59	4.01
Cages	$\bar{x}$	(g)	32.70	37.69	37.91	37.54	38.26	39.07	36.18	39.11	37.31
	sd	(g)	3.42	3.47	3.70	3.80	4.25	4.04	3.34	4.08	4.21
	P		0.50	0.15	0.04*	0.08	0.04*	0.12	0.00**	0.43	0.00**
Deep litter	$\bar{x}$	(%)	64.45	63.76	63.39	62.16	61.18	61.25	60.46	61.87	62.32
	sd	(%)	2.12	2.05	2.41	2.00	3.00	2.32	2.57	3.80	2.88
Cages	$\bar{x}$	(%)	64.72	64.03	62.39	61.77	60.43	61.30	58.18	59.94	61.59
	sd	(%)	2.45	2.58	3.21	5.30	3.30	3.56	3.59	2.35	3.92
	P		0.62	0.62	0.14	0.68	0.31	0.95	0.00**	0.01**	0.01**

$\bar{x}$ = arithmetic mean; sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

tistically highly significant in the total number in absolute values and also in the calculation of the proportion of egg albumen weight in egg weight (%). Similar findings were reported by Basmacioglu and Ergul (2005).

Yolk weight was an additionally monitored parameter. The results are given in Table 5. It follows from the table that there was no statistically significant difference in the weight of yolk from the deep litter system and from the cage system,

Table 5. Yolk weight

Collection			1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	(g)	11.61	14.92	15.84	16.47	17.63	17.78	17.78	17.15	16.15
	sd	(g)	1.15	0.96	1.44	1.55	1.57	1.34	1.63	1.71	2.42
Cages	$\bar{x}$	(g)	11.40	14.23	15.70	16.63	17.09	17.26	17.99	17.77	16.01
	sd	(g)	1.10	1.27	1.43	1.58	1.85	1.81	2.28	1.13	2.62
	P		0.43	0.01**	0.68	0.67	0.19	0.18	0.64	0.08	0.51
Deep litter	$\bar{x}$	(%)	23.31	24.59	25.33	26.30	26.94	27.04	27.65	26.71	25.98
	sd	(%)	1.91	1.79	2.45	1.98	2.07	2.13	2.62	2.64	2.59
Cages	$\bar{x}$	(%)	22.67	24.25	25.93	27.37	27.04	27.12	28.98	27.40	26.34
	sd	(%)	2.22	2.14	2.47	2.36	2.50	2.12	3.42	2.34	3.09
	P		0.20	0.47	0.31	0.04*	0.85	0.87	0.07	0.25	0.13

$\bar{x}$ = arithmetic mean; sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

Table 6. Yolk cholesterol (%)

Collection		1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	1.27	1.07	1.24	1.14	1.18	1.13	1.13	1.19	1.17
	sd	0.13	0.12	0.09	0.07	0.07	0.09	0.11	0.09	0.12
Cages	$\bar{x}$	1.13	1.04	1.14	1.15	1.11	1.14	1.10	1.12	1.12
	sd	0.16	0.12	0.05	0.10	0.10	0.10	0.09	0.09	0.11
	P	0.00**	0.32	0.00**	0.42	0.00**	0.70	0.25	0.00**	0.00**

$\bar{x}$ = arithmetic mean; sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

Table 7. Yolk colour

Collection		1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	6.19	8.00	6.81	6.81	6.83	6.33	6.03	5.64	6.58
	sd	0.92	0.96	0.67	0.47	0.81	0.68	0.45	0.49	0.97
Cages	$\bar{x}$	7.09	7.06	6.44	6.19	6.42	5.92	6.36	5.94	6.43
	sd	1.11	0.71	0.73	0.67	0.73	0.69	0.68	0.58	0.85
	P	0.00**	0.00**	0.03*	0.00**	0.03*	0.01**	0.02*	0.02*	0.05*

$\bar{x}$ = arithmetic mean; sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

Table 8. Shell strength (N)

Collection		1	2	3	4	5	6	7	8	Total
Deep litter	$\bar{x}$	32.18	34.63	33.67	28.47	34.92	32.99	30.77	29.38	32.13
	sd	11.27	10.68	8.33	9.90	7.28	8.57	9.85	10.01	9.71
Cages	$\bar{x}$	16.05	32.37	32.52	30.86	36.70	32.68	34.31	29.60	30.64
	sd	5.89	7.81	11.76	10.74	8.11	11.10	9.07	9.72	11.03
	P	0.00**	0.31	0.63	0.33	0.33	0.89	0.12	0.93	0.09

$\bar{x}$ = arithmetic mean; sd = standard deviation; *P* = statistical significance; * = statistically significant $P < 0.05$; ** = statistically highly significant $P < 0.01$

namely both in absolute values and in the calculation of the proportion of yolk weight in egg weight (%). Basmacioglu and Ergul (2005) reported higher yolk weight in hens reared in cages.

We discovered that the egg weight was higher in the deep litter system. The higher weight of egg albumen in the deep litter system was discovered as well. The yolk weight did not change. Different findings were reported by Anderson and Adams (1994). They stated that hens reared in cages produced heavier ($P < 0.001$) eggs with a higher percentage of Grade A eggs. We can state that egg weight is influenced by the laying hen breed, as reported by Halaj et al. (1998) and Basmacioglu and Ergul (2005), and by the group size of laying hens which are kept together as stated by Keeling et al. (2003), and according to our results, the deep litter technology also influences egg weight. Conversely, according to Tumova and Ebeid (2005) the time of oviposition does not influence egg weight. Furthermore, it follows from our results that we can confirm the finding, both for the cage system and aviary system, which was described by Jiang and Sim (1991), that the egg weight and yolk weight (absolutely and also in percentage of egg weight) increase during the first 6 months of egg-laying period.

Yolk cholesterol was an additional parameter that was monitored. The results are shown in Table 6. It follows from the table that yolk cholesterol was higher in eggs from the deep litter system and this difference was statistically highly significant in the total number.

We found the higher yolk cholesterol content in the deep litter system. The same experience was made by Basmacioglu and Ergul (2005), who found out that eggs from hens reared in cages contained significantly more cholesterol than did eggs laid by hens reared in floor pens. The cholesterol content in eggs is important from the viewpoint of human nutrition as stated by Simeonovova et al. (1992). The deep litter system of laying hen keeping with the replacement of animal protein with vegetable protein is thus burdened with the issue of the cholesterol content. We, and Maurice et al. (1994), did not find any influence of laying hen age on the cholesterol level in egg yolk from laying hens kept in either deep litter system or cage system.

Furthermore, yolk colour was monitored. The results are shown in Table 7. It follows from the table that the yolk colour was found darker in eggs from the deep litter system and this difference was statistically significant in the total number and also in individual intervals of monitoring.

We found out that the yolk colour was darker in the deep litter system. Here we confirmed the results published by Van den Brand et al. (2004), who also found a darker yolk colour in laying hens that were not kept in cages. This finding is important from the viewpoint of information mentioned by Nys (2000) that darker yolk colour can be preferred by consumers.

The results of monitoring the shell strength are given in Table 8. It follows from the table that the difference in the shell strength in eggs from the deep litter system and in eggs from the cage system was not found statistically significant. The same results were reported in the study of Leyendecker et al. (2002), who found out lower eggshell stability only in the hens kept in furnished cages.

Ledvinka et al. (2000) concluded that the shell quality was one of the most important parameters for the technology of further egg manipulation. We discovered that the shell weight was higher in the cage system, however, there was no difference in the shell strength. A comparison of the deep litter and conventional cage system in which animal protein in the feed was replaced by vegetable protein shows that the shell quality was not influenced.

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