The effects of housing systems and age of hens on the weight and cholesterol concentration of the egg

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ABSTRACT: The effects of laying hen age and the housing of laying hens in conventional cages, enriched cages, litter system and outdoor system on egg weight and yolk and egg cholesterol concentration were studied. ISA brown laying hens were used in the experiment. The characteristics were measured at 39, 50, 59, 68 and 75 weeks of age. Fifteen eggs were always collected from each housing system. In total, 300 eggs were analyzed. There were not any significantly different results in the eggs from the hens living in the different housing systems or from the age of laying hens on the weight of eggs. But the housing system and the age of hens had a significant ($P \leq 0.01$) effect on both yolk and egg cholesterol concentration. The concentration of yolk and egg cholesterol was the lowest ($P \leq 0.01$) in the enriched cages (12.5 mg/g yolk and 211.2 mg/egg) and the highest in the litter technology (14.1 mg/g yolk and 242.6 mg/egg). Further, there was a significant ($P \leq 0.01$) influence of the interaction between the housing system and the age of hens on egg weight and on yolk and egg cholesterol concentration.

Keywords: conventional cages; enriched cages; litter system; outdoor system; yolk cholesterol; egg weight

According to Council Directive 1999/74/EC of 19 July 1999 the poultry rearing in conventional cages will be prohibited starting on 1 January 2012. Therefore, the use of alternative housing systems (outdoor and litter technologies) or enriched cages will be mandatory.

Some studies indicated that the egg weight was higher in cage systems than in the other housing technologies (Mohan et al., 1991; Leyendecker et al., 2001). Contrary to these studies Basmacioglu and Ergul (2005), and Thomas and Ravindran (2005) observed that the egg weight was not influenced by the housing system. Tůmová and Ebeid (2005) recorded higher egg weight in a litter system. Van den Brand et al. (2004) demonstrated that the weight of eggs from outdoor layers was lower at an early age, but increased more with age than in the eggs from hens in cages. The age of hens is an important factor affecting the weight of eggs. A lot of authors (Jiang and Sim, 1991; O'Sullivan et al., 1991; Peebles et al., 2000; Silversides and Scott, 2001; Oloyo, 2003; Van den Brand et al., 2004) confirmed that the egg weight increased with the hen's age. Chand (1987) indicated significant differences ($P \leq 0.01$) in egg weight between periods during the 1st laying season.

The age of hens and the housing system can also affect the concentration of cholesterol in the eggs. Basmacioglu and Ergul (2005) revealed that the rearing system significantly affected the egg cholesterol concentration. Sauveur (1991) and Premavalli et al. (2005) reported a lower egg cholesterol concentration in laying hens housed in cages compared with laying hens housed on deep litter. On the contrary, Cerolini et al. (2005) did not observe any significant changes in the cholesterol concentration of eggs from hens in different housing systems. Similarly, Tůmová and Ebeid (2005) did not prove any significant differences in the cholesterol concentration between the cage and litter systems. Different conclusions also exist about the effect of the age of hens on the cholesterol concentration. Pandey et al. (1989) revealed that the cholesterol levels in eggs decreased as the age of hens increased. Contrarily, Jiang and Sim (1991) found an increasing cholesterol level with age (mg/egg), but the yolk cholesterol concentration (mg/g yolk) decreased during the first 6 months of egg production. Oloyo (2003) confirmed this result and found that yolk cholesterol (mg/g yolk) was significantly higher ($P \leq 0.05$) in younger birds. Chung et al. (1991) and Shafey et al. (1998) found a positive correlation between the cholesterol concentration (mg/g yolk) and the hen's age. Contrarily, Li Yun Lin and Min Hsiung Lee (1996) concluded that the yolk cholesterol concentration did not differ significantly with the hen's age.

The objective of the present study was to determine the effects of the housing system and the age of hens on the concentration of cholesterol and the weight of eggs.

MATERIAL AND METHODS

The laying hens were housed in conventional cages, enriched cages, litter system and outdoor system according to Council Directive 1999/74/EC.

Three hundred twenty-two ISA brown laying hens were used in the experiment. A total of 196 hens were housed (550 cm^2 per hen) in conventional cages (four-floor system). Enriched cages met the requirements of EU Directive 1999/74/EC (750 cm^2 per hen) and 80 hens were housed in these cages. Shavings, an automatic nest and an automatic drinking system were used in the litter system. Thirty-four laying hens were housed in this system (17 laying hens per 4 m^2). In the outdoor system, 12 hens were housed as they would be kept on a typical small farm. The hens had 5 m^2 of litter with a place for scratching, 3 nests, and an outdoor run (2 m × 5 m).

The eggs were collected from the hens between week 39 and 75 of age, at 39, 50, 59, 68 and 75 weeks of age. 15 eggs from each housing system and in the whole range of weights were collected at each of those weeks, and a total of 75 eggs from each system were analyzed. The laying hens were fed

Table 1. The composition of diets

Diets	N1	N2
Ingredients		
Maize (%)	40.0	40.0
Wheat (%)	29.5	29.5
Soybean meal (%)	17.0	16.0
Fish meal (%)	3.1	3.1
Supplementary premix (%)	10.4	11.4
Nutrient composition		
ME (calculated) (MJ/kg)	11.1	11.05
Dry matter (g/kg)	875.0	877.0
Crude protein (g/kg)	170.7	169.2
Fibre (g/kg)	25.95	25.87
Calcium (g/kg)	35.89	38.55
Phosphorus (g/kg)	6.27	6.29
Methionine (g/kg)	3.87	3.81
Sulphurous amino acid (g/kg)	5.84	5.81
Threonine (g/kg)	6.16	6.11
Sodium (g/kg)	1.69	1.70
Magnesium (g/kg)	1.44	1.54
Manganese (mg/kg)	98.8	99.5
Zinc (mg/kg)	79.7	80.3
Vitamin A (IU/kg)	8 000	8 000
Vitamin D (IU/kg)	1 800	1 800
Vitamin E (mg/kg)	18.6	18.6
Riboflavin (mg/kg)	5.4	5.5
Vitamin B12 (μg/kg)	16	16
Biotin (mg/kg)	0.082	0.082
Choline (mg/kg)	1 128	1 132

ad libitum the diet N1 to 50 weeks of age and the diet N2 from week 51 of age in all housing systems. Table 1 shows the ingredients of the diets and their nutrient composition. The nutrient content was calculated. The hens that could go outside also ate forage *ad libitum* in the growing season.

After weighing the eggs, the yolk was separated from the albumen and chalaza with filter paper. The yolks were weighed. The modified method Bio-La test (Ingr and Simeonová, 1983) was used to determine the cholesterol concentration. The egg cholesterol concentration was calculated after determining the yolk cholesterol concentration by using the individual weight of each egg.

All data were analyzed by the statistical system Unistat using the analysis of variance. Statistical differences between the individual housing systems and the weeks of age were tested by Scheffe's method. The interactions of housing system and hen's age were analyzed by *F*-test.

RESULTS AND DISCUSSION

The data in Table 2 shows that there were not any significant effects of housing systems on the weight of eggs (except at 39 weeks of age). These results are in agreement with Basmacioglu and Ergul (2005), and Thomas and Ravindran (2005), who indicated that the housing system did not have a significant effect on egg weight. But Mohan et al. (1991) and Leyendecker et al. (2001) determined higher egg weight in cages than in alternative systems. Tůmová and Ebeid (2005) observed higher egg weights in the hens that were housed in the litter system, but this conclusion was not confirmed in our study. The average egg weight was 66.2 g in conventional cages, 66.0 g in enriched cages, 66.3 g in the litter system and 67.9 g in the outdoor system.

Data reported by Van den Brand et al. (2004) documented that egg weight increased with the age of hens. This was not confirmed by our study, because the highest egg weight was at 59 weeks of age in hens that were housed in conventional cages. The egg weight of the laying hens that were housed in the outdoor system decreased until they were 59 weeks of age, and then the egg weight increased (Table 2). In enriched cages and litter system, the egg weight increased (with few exceptions). These results agree with the results of many authors, e.g. Jiang and Sim (1991), O'Sullivan et al. (1991), Peebles et al. (2000), Silversides and Scott (2001), Oloyo (2003) and Van den Brand et al. (2004), who showed that egg weight increased with the increasing age of hens. Regardless of the type of housing systems the egg weight increased only slightly, depending on the age of laying hens. The data in Table 2 shows that there was a significant influence ($P \leq 0.01$) of the interaction between the housing system and hen's age on the weight of eggs.

In our study we expressed the results of cholesterol concentration as yolk cholesterol concentration and egg cholesterol concentration. A significant effect of housing systems on the yolk cholesterol concentration (mg/g yolk) was observed each week (except at 59 week of age, the differences between the groups were not significant). The average yolk cholesterol concentration (mg/g yolk) was the lowest in enriched cages (12.5 mg/g yolk). The highest yolk cholesterol concentration was noted in the eggs from the litter system (14.1 mg/g yolk). The eggs from conventional cages had the average yolk cholesterol concentration of 13.3 mg/g yolk and the eggs from the outdoor system contained 13.4 mg/g yolk. The yolk cholesterol concentration in the eggs from the outdoor system might be influenced by forage intake. Our result is in agreement with Basmacioglu and Ergul (2005), who proved that the housing system had a significant effect on the cholesterol concentration. Premavalli et al. (2005) showed that the eggs laid by the birds in the elevated cage system had significantly ($P \leq 0.01$) lower yolk cholesterol (11.29 mg) than those from the deep litter system (11.58 mg). Similarly, Sauveur (1991) observed a significant increase in the egg cholesterol from the hens housed in alternative housing systems. Tůmová and Ebeid (2005) examined the effects of the time of oviposition on yolk cholesterol in the cage system and litter system. No significant differences were detected between the eggs laid in the morning and those laid in the afternoon. These authors also reported only a small difference between the effects of different housing systems on the yolk cholesterol concentration. Cerolini et al. (2005) studied the cholesterol concentration in the eggs from hens in four housing systems: organic, with outside pen, floor system and battery cages. The average content of cholesterol was 370 mg/100 g edible egg and no significant changes were observed between the groups, unlike our results.

The data in Table 2 shows that there were significant differences in the egg cholesterol concentration (mg/egg) between the eggs laid in different housing systems. The results were similar to the

Table 2. The effect of the housing system and hen's age on egg weight and cholesterol concentration

Characteristic	Age of hens (weeks)	Housing system: conventional cages	Housing system: enriched cages	Housing system: litter system	Housing system: outdoor system	Significance: housing system	Significance: age of hens	Significance: housing system x age
Egg weight (g)	39	62.9	65.7	63.6	69.7	NS	NS	**
	50	63.5	64.4	67.9	67.4			
	59	70.1	66.3	66.2	65.8			
	68	65.9	66.5	66.8	68.9			
	75	68.6	67.0	66.9	67.5			
	all in housing system	66.2	66.0	66.3	67.9			
Yolk cholesterol concentration (mg/g yolk)	39	15.1	14.1	15.5	13.5	**	**	**
	50	13.2	11.5	13.2	12.8			
	59	11.6	11.2	11.8	12.2			
	68	13.8	12.5	16.1	15.4			
	75	12.8	13.1	14.2	13.0			
	all in housing system	13.3	12.5	14.1	13.4			
Egg cholesterol concentration (mg/egg)	39	243.5	229.9	259.7	235.8	**	**	**
	50	224.1	194.4	230.5	222.1			
	59	214.1	193.1	208.4	201.1			
	68	238.0	212.9	272.9	262.4			
	75	235.8	225.9	243.5	219.9			
	all in housing system	231.2	211.2	242.6	228.5			

**$P \le 0.01$; *$P \le 0.05$; NS = not significant results of yolk cholesterol (mg/g yolk). The lowest average egg cholesterol concentration was in the eggs from enriched cages (211.2 mg/egg). The highest average concentration was in the eggs from the litter system (242.6 mg/egg). In the eggs from the outdoor system, the average concentration of cholesterol was 228.5 mg/egg and in the eggs from conventional cages, 231.2 mg/egg. Significant differences were detected in the eggs from different housing systems during each week of observation (except during weeks 59 and 75). We point out the potential influence of forage intake on the egg cholesterol concentration in the eggs from the outdoor system.

In Table 2, the effect of age on the concentration of cholesterol in yolks (mg/g yolk) and eggs (mg/egg) is shown for the eggs in each housing system. The effect of age on both characteristics was almost identical. The yolk and egg cholesterol concentration decreased at 50 and 59 weeks of age. At 68 weeks of age the concentration of cholesterol increased, and at 75 weeks of age it decreased again. A significant effect of the hen's age on the egg cholesterol concentration (mg/egg) and yolk cholesterol concentration (mg/g yolk) was found. But no correlation was calculated between the laying hen age and the concentration of cholesterol in the eggs. The results of Chung et al. (1991) and Shafey et al. (1998) that the age of the hen is significantly positively correlated with yolk cholesterol concentration were not confirmed. Our values are in agreement with Chung et al. (1991), who reported that the cholesterol concentration ranged from 12 to 15 mg/g yolk and that the mean value for all eggs was 13.0 mg/g or 221 mg/egg. In our study the average yolk cholesterol concentration was 13.3 mg/g yolk and the average egg cholesterol concentration was 228.3 mg/egg. Oloyo (2003) confirmed that the cholesterol concentration (mg/g yolk) was higher ($P \leq 0.05$) in younger birds. This is in agreement with our results. But at 68 weeks of age, the yolk cholesterol concentration increased again. Pandey et al. (1989) revealed that the cholesterol level in the egg decreased with the age of hens. This is similar to our finding, but only until 59 weeks of age. Jiang and Sim (1991) indicated that as the laying hens aged, the egg cholesterol concentration (mg/egg) increased, but the yolk cholesterol concentration (mg/g yolk) decreased during the first 6 months of egg production. These findings agree with our results to a certain extent, because we found that the yolk cholesterol decreased to 59 weeks of age. The results of this study are not consistent with Li Yun Lin and Min Hsiung Lee (1996), who found that the yolk cholesterol concentration did not differ significantly with the age of the hen.

The data in Table 2 shows that there was a significant ($P \leq 0.01$) effect of the interaction between the housing system and the age of the hens on yolk cholesterol concentration. A significant ($P \leq 0.01$) influence of the interaction between the hen's age and the housing system was also found for egg cholesterol concentration.

Our study demonstrated that the egg weight is not influenced significantly either by the housing system or by the age of the hens (after 39 weeks of age). But, the interaction between the housing system and the hen's age had a significant effect on egg weight. Next the housing system, the age of the hens and their interaction had an effect on the cholesterol concentration of the yolk and the egg. The lowest average cholesterol concentration was in the eggs from enriched cages. The highest was in the eggs from the litter system. In the eggs from conventional cages and outdoor system the values were alike. We emphasize that the hens in the outdoor system ate forage. That might influence the cholesterol concentration in the eggs from the outdoor system. In our research the yolk cholesterol and egg cholesterol concentration decreased with the increasing age of hens to 59 weeks of age. Then the content of cholesterol increased to 68 weeks of age and then it decreased again. There was no linear regression between the concentration of cholesterol in the eggs (yolks) and the age of the laying hens.

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