

LAYER PERFORMANCES, EGGSHELL CHARACTERISTICS AND BONE STRENGTH IN THREE DIFFERENT HOUSING SYSTEMS

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Abstract: The aim of this study was to determine the effects of three different housing systems for laying hens (cages, barn and organic) on layer performances, eggshell characteristics and bone strength. In each system, the same strain of laying hens (Hyline Brown®) was housed in agreement with current European regulation and the hens were fed on the same level of nutrition (2800 ME). The study was conducted over one year period in three typical farms in the north of Italy, from the 18th to the 70th weeks of layers age. The number of eggs collected and laid on the floor were recorded weekly, as well as the mortality and the feed consumption. At 27, 30, 35, 43, 53 and 68 weeks of layers age, the weight and the shell characteristics of eggs from the different systems were analysed. Bone breaking strength and stiffness were determined by three point bending test. The percentage of deposition was generally higher in comparison to the standard production of Hyline hens, probably, due to a high management standard and to the production persistence. The results indicated a clear relationship between the percentage of cracked eggs and the strength characteristics of the shells, with organic eggs showing the highest shell thickness, the most resistant shell and consistently the less cracked eggs. Considering the changes that occur during the laying cycle, shell strength and thickness in non-cage eggs were highly affected by hen age, while they were much stable in cage eggs. Organic hens also showed the strongest humerus, while their tibiotarsus were as robust as those of cage hens.

Keywords: layer performances, eggshell characteristics, bone strength, housing system

Introduction

In the last 20 years conventional cages for laying hens have been extremely

criticized in the European Community, because they restrict the birds' movement and prevent them from performing natural behaviours such as nesting, perching and dust bathing (*Duncan and Fraser, 1997; Leyendecker et al., 2005*). Moreover, birds housed in conventional cage may develop cage layer osteoporosis that leads to bone breakage and early death (*Wilson et al., 1992; McCoy et al., 1996*). Thus, osteoporosis induced by the high demands for calcium during eggshell production in layers has become a serious problem for the egg industry (*Fleming et al., 1996*). The costs associated with reduced productivity and increased mortality due to calcium deficiency have been recognized since the mid 1950s when battery cage housing for layers first became popular (*Leeson et al., 1995*). *Gregory and Wilkins (1989)* showed that skeletal damage was a major welfare problem in laying hens and more recent studies suggested that bone fractures caused by osteoporosis are an increasingly serious welfare issue (*Budgell and Silversides, 2004; Sandilands et al., 2005*). In these studies incidences of old healing fractures of up to 70% were recorded depending upon husbandry system and bird strain. Cage housing is associated with reduced bone strength compared with barn (*Barnett et al., 1998*), aviary (*Leyendecker et al., 2005*) or free-range (*Gregory et al., 1990*) systems. However, while more extensive housing can lead to increased bone strength, there are also increased opportunities for injuries such as feather pecking, peck injury and peck mortality (cannibalism). Many hen welfare concerns are not intrinsically linked to housing system although this is one factor out of more that influences the welfare of the birds. Other factors such as genetics, the environment the hen was raised in and the quality of human handling must also be considered (*Graml et al., 2008*). For instance, genetic selection may produce laying hens that are less prone to bone weakness (*Webster, 2004*). Bone strength is better when more space is available and there is the presence of equipment details promoting activity e.g. perches (*Fleming et al., 1994; Freire et al., 2003*). Especially hens in conventional cages may risk having their wing bones broken at the end of lay and hence experienced and gentle catching and handling methods are important (*Gregory et al., 1994*). Hens in aviaries however have a higher risk of breaking their fulcrum and keel bones during the laying period by collisions with equipment or other birds (*Freire et al., 2003*). The perch design has been shown to have a considerable impact on the incidence of keel bone deviations mainly through differences in impact pressure on this part of skeleton (*Tauson and Abrahamsson, 1994*). The possibility to jump during rearing period reduces skeletal damage in the following production period (*Michel and Huonnic, 2003*). Although the limitations of space may vary according to stocking density, there are several reports on the negative effects on bone strength, which in turn may lead to bone fragility and eventually, breakage of parts of skeleton e.g. during depopulation at the end of the laying cycle (*Fleming et al., 1994*). Nutrition and management of the birds are important in maximizing the mineralization of skeleton, ultimately minimizing the severity of osteoporosis, which will occur as hen laying cycle progresses. However, it appears

that even with optimal calcium, phosphorus and vitamin D3 levels in the diet, osteoporosis is still likely to occur to some degree in the highly productive layers (Whitehead, 2004; Leeson *et al.*, 1995). Egg quality is affected by a range of factors including the strain and the age of the hen, the diet and the housing system. The environmental conditions within the house can also influence the egg quality through a modification of the birds' physiological status (Travel *et al.*, 2011).

A major impact has the bird age which affect the egg weight, the proportion of the different egg components and composition, and the eggshell quality. The egg weight increases with hen age varying between 50 and 70 g, however most modern commercial strains are now capable of achieving egg weights of 60 g by 26 weeks of age and 65.5 g by 50 weeks, and sustaining this until the end of production (Nys *et al.*, 2008).

The influence of the bird age on the eggshell quality bears an increase in the percentage of cracked and broken shells, ranging from 2-5% at the beginning of laying to values up to 12-20% in older hens (Nys *et al.*, 2008). This is consistent with the reduction in the eggshell percentage and breaking strength observed with the increasing egg weight during hen aging (Casiraghi *et al.*, 2005).

Minor influence on eggshell quality is reported for the different housing systems. In a review by Rossi and De Reu (2011), it was concluded that nest eggs of non cage systems are normally not more susceptible to cracks than those of cage eggs. However, general conclusions on the effect of cage and non-cage housing systems on egg weight, shell strength and thickness could not be drawn because of inconsistencies of results from different authors in the literature. As suggested by Van den Brand *et al.* (2004), ambiguities or contrasts among the studies might be explained by differences in the amount of dietary Ca and available P, which can strongly affect shell quality.

The aim of the present study was to determine the effects of three different housing systems for laying hens (cage, barn and organic) on layer performances, eggshell quality and bone strength.

Materials and Methods

The study was carried out in three Italian layer farms over one year period, with hen aged from 18 to 70 weeks. A comparison was made among laying hens in three rearing technologies: conventional cage (C), barn (litter floor, B) and organic system (O), on the same level of nutrition, same season and bird flock. In each system, laying hens of the same strain (Hyline Brown®) were housed in agreement with Council Directive 1999/74 (EU, 1999) and Regulation (EC) No 834/2007 (EU, 2007) about organic production.

The experiments were carried out before the coming into force (1/1/2012) of the ban of conventional cages for laying hens in the European Union in favour of alternative housing systems, or furnished cages systems (EU, 1999).

The study involved 32429 Hyline Brown® layers. Birds were beak-trimmed, transferred from rearing to laying systems in July when 18 weeks old and slaughtered at week 70. Microclimate and lighting conditions for rearing followed the technological standard for the rearing of this hybrid.

Conventional battery cages of 20 cm x 40 cm x 40 cm were used, according to European Directive 1999/74/EC (*EU, 1999*), which stated that each hen should have at least 550 cm² available space.

Farm B was a typical barn (12 m x 42 m) with 1/3 of litter and 2/3 of slat. The stocking density was 9.4 birds/m². Sixteen hours of light/day was provided through lateral windows located along the two longest walls, and artificial lighting program.

In farm O a free-range area (9000 m²) was accessible through 16 doors (35 cm x 100 cm, in agreement with Regulation (EC) No 834/2007 (*EU, 2007*)). The indoor poultry farm (5 m x 75 m) was divided in three parts: litter (1/3 of whole area), slat with drinking and feeding areas, and nests. The stocking density was 5.4 birds/m².

The hens were fed a standard layer diet containing 2800 ME. Food and water were provided ad libitum in all housing systems.

The total number of laid eggs were recorded weekly, as well as the number of second category eggs, hen mortality and feed conversion rate (FCR).

At 27, 30, 35, 43, 53 and 68 weeks of layers age, 100 eggs from each system were collected. The eggs were weighed and candled to measure the percentage of cracked eggs and to select intact eggs for successive analysis. Thirty intact eggs from the original 100 were manually broken and voided. The shells were wiped and weighed without removing the membranes. Shell thickness was then measured at the equator in triplicate, using a 550-501 digital micrometer (NSK, Japan).

Another group of 30 intact eggs were used to calculate the surface area of each egg (*Thompson et al., 1985*) and the shell index as the ratio between egg weight and its surface area. The same 30 eggs were used to perform mechanical analyses. Shell breaking strength (N) was measured using an Instron Universal Testing Machine 4301 (Instron Ltd, High Wycombe, England) supported by the Series IX Automated Material Testing System software. Compression tests were carried out on seven individual eggs per sample, at the constant cross-head speed of 20 mm/min using a 100 N load cell. A 35 mm diameter plate was used as a compression device. Strength (N), displacement (mm) and energy (mJ) at breaking point were determined.

Twenty hens per housing system were randomly chosen and slaughtered at 70 weeks of age. The right tibiotarsus and humerus were cleaned of flesh and stored at -20°C until analyses. After thawing, the major and minor diameters were measured in the centre of the bones with a calliper, and a mean centre diameter was calculated. Bone breaking strength and stiffness were determined by a three point

bending test, carried out using the Instron Universal Testing Machine 4301. The bones were placed on the support (30 mm apart for humerus and 65 mm apart for tibia), laying down on the major diameter and aligning the centre of each bone with the breaking probe. Analyses were carried out at room temperature, with a constant cross-head speed of 20 mm/min and a load cell of 1kN. Results are expressed as breaking strength (N), corresponding to the fracture load, and stiffness (N/mm), calculated as the slope of the linear portion of the force-deformation curve.

Statistical analysis. The data related to the characteristics of downgraded eggs at different ages were analysed using the non parametric analysis of variance of SPSS Version 18.0 software (test Wilcoxon) with housing system as the main effect. Shell and bone characteristics were analysed by ANOVA, considering housing systems and hen age as factors and the two-way interaction for shell data, while for bones the factor was only the housing system. The significance controls of the differences were determined by LSD test. Both ANOVA procedure and LSD test were performed using Statgraphics Plus Version 4.0 software (StatPoint Inc., Herndon, VA, USA). Correlation analysis among variables was performed using Systat software Version 5.0 (Systat Software Inc., Richmond, CA, USA) following the Pearson approach.

Results and discussion

Layer performances. Production performances of hens were recorded between 18 and 70 weeks of age (Figure 1). Hen-housed egg production (eggs laid*100/number of hens at time of recording) was similar among the housing systems being 84.9% (O), 86.4% (B) and 85.4% (C) ($P > 0.05$). After reaching the peak of lay at about 24 wk, the level remained steady, then as expected decreased overtime. As shown in Figure 1, in comparison to the standard production of Hyline (Hyline, 2007) at the same week of deposition, the percentage of deposition was generally higher, especially in the organic and barn systems, due probably to high management level and to the production persistence.

The number of laid eggs obtained per hen was identical in the different systems, with a mean weekly production rate of 6 eggs/hen in all systems.

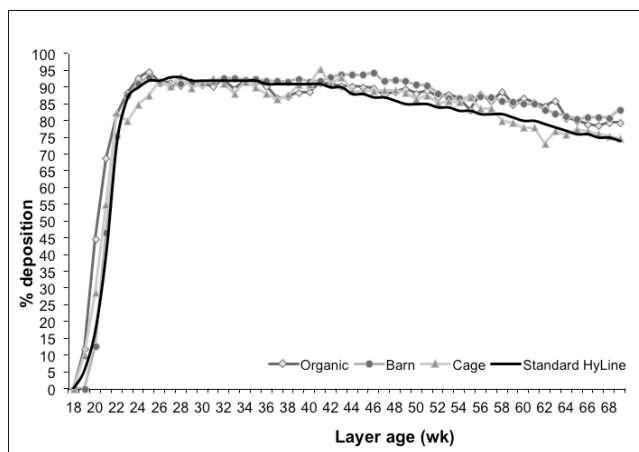


Figure 1: Egg deposition (%) in relation to layer age and housing system

Egg weight and eggshell characteristics. The mean values of egg weight and eggshell characteristics for the three housing systems and for different hen ages are reported in Tables 2 and 3, respectively. The ANOVA evidenced significant differences for all the variables and all factors (housing system (S), hen age (A) and S x A), with the exception of the displacement measurement obtained in the compression test that was not affected by housing system.

On average, barn system produced the heaviest eggs (Table 1) and consistently the highest number of cracked eggs, the greatest surface area and the lowest shell thickness and breaking strength.

Table 1. Mean values and pooled standard error (pooled SEM) of the shell characteristics of eggs from hens reared in three different housing systems during the whole production cycle

Variable	Housing system			Pooled SEM	P
	Cage	Barn	Organic		
Cracked eggs (%)	6.4 ^b	10.3 ^c	3.8 ^a	1.6	0.033
Egg weight (g)	62.9 ^a	66.0 ^c	63.9 ^b	0.4	0.000
Shell percentage (%)	10.9 ^a	11.0 ^{ab}	11.1 ^b	0.1	0.004
Egg surface area (cm ²)	73.5 ^a	75.8 ^b	74.2 ^a	0.5	0.000
Shell index (g/cm ²)	0.092 ^a	0.095 ^b	0.095 ^b	0.001	0.001
Shell thickness (mm)	0.463 ^b	0.456 ^a	0.476 ^c	0.005	0.000
Compression test					
Strength (N)	37.8 ^b	35.1 ^a	40.1 ^c	0.9	0.000
Displacement (mm)	0.27	0.27	0.27	0.0	0.257
Energy (mJ)	5.8 ^b	5.5 ^a	6.3 ^c	0.2	0.000

P represents the significance level of the "Housing system" factor for ANOVA; different letters in the same row indicate significant differences at $P \leq 0.05$ following LSD test.

Table 2. Mean values and pooled standard error (pooled SEM) of the shell characteristics of eggs from hens of different ages (from 20 to 68 weeks) reared in different housing systems

Variable	Average hen age (weeks)			Pooled SEM			P	
	27	30	35	43	53	68		
Cracked eggs (%)	3.1 ^a	5.2 ^a	4.7 ^a	5.9 ^a	4.7 ^a	17.3 ^b	1.8	0.007
Egg weight (g)	60.7 ^a	62.1 ^b	64.1 ^c	66.0 ^d	66.0 ^d	66.6 ^d	0.8	0.000
Shell percentage (%)	10.4 ^a	10.9 ^b	10.8 ^b	11.6 ^d	11.4 ^c	10.8 ^b	0.2	0.000
Egg surface area (cm ²)	72.1 ^a	73.3 ^b	74.7 ^c	75.5 ^{cd}	75.4 ^{cd}	76.0 ^d	1.0	0.000
Shell index (g/cm ²)	0.088 ^a	0.093 ^b	0.092 ^b	0.100 ^d	0.098 ^c	0.093 ^b	0.002	0.000
Shell thickness(mm)	0.457 ^{ab}	0.466 ^{cd}	0.465 ^{bc}	0.480 ^e	0.476 ^{de}	0.449 ^a	0.009	0.000
Compression test								
Strength (N)	37.0 ^b	38.5 ^{bc}	38.9 ^c	40.0 ^c	38.4 ^{bc}	32.9 ^a	1.7	0.000
Displacement (mm)	0.26 ^b	0.27 ^{bc}	0.28 ^c	0.29 ^d	0.27 ^{bc}	0.25 ^a	0.01	0.000
Energy (mJ)	5.7 ^b	6.1 ^c	6.2 ^{cd}	6.5 ^d	5.8 ^{bc}	4.7 ^a	0.4	0.000

P represents the significance level of the "Hen age" factor for ANOVA; different letters in the same raw indicate significant differences at $P \leq 0.05$ following LSD test.

On average, cage eggs were the smallest and consistently presented the lowest shell percentage and surface area; shell index of cage eggs was also the lowest, although with values intermediate between barn and organic eggs for cracked eggs, shell thickness, strength and energy. These results indicate a clear relationship between the percentage of cracked eggs and shell breaking strength. Actually, a significant negative correlation ($P < 0.001$; $R = 0.997$) was observed between shell strength and cracked eggs. Moreover, shell resistance seems to be more dependent on shell thickness than on egg weight. In fact, significant correlations ($P < 0.001$) were found for shell thickness vs shell strength and energy ($R = 0.902$ and $R = 0.828$, respectively), while no correlation was found between shell strength and egg weight. However, an indirect correlation ($P < 0.05$) between egg weight and shell breaking strength was previously reported by *Casiraghi et al. (2005)* for cage eggs of the size S, M, L, and XL and by *Clerici et al. (2006)* ($P < 0.01$) for eggs from hens aged 28-64 wk reared in cage, free-range, barn and organic systems.

Bone strength. Mean values and standard errors of the bone characteristics of hens at the end of the production cycle are reported in Table 3. As evidenced by the ANOVA results, the housing system had a significant effect on the tibiotarsus and humerus breaking strength and stiffness. In particular, hens reared in the organic system showed tougher humerus with respect to cage and barn hens, whereas the tibiotarsus was stronger only if compared with barn hens.

Table 3. Mean values and pooled standard error (pooled SEM) of the bone characteristics at the end of the production cycle of hens reared in three different housing systems

Variable	Housing system			Pooled SEM	P
	Cage	Barn	Organic		
Tibiotarsus					
Breaking strength (N)	157 ^{ab}	146 ^a	171 ^b	9.2	0.0072
Stiffness (N/mm)	157 ^b	143 ^a	162 ^b	7.2	0.0071
Centre mean diameter (mm)	7.2 ^a	7.4 ^a	7.6 ^b	0.1	0.0039
Humerus					
Breaking strength (N)	150 ^a	182 ^b	211 ^c	13.7	0.0000
Stiffness (N/mm)	197 ^a	229 ^b	276 ^c	17.9	0.0000
Centre mean diameter (mm)	7.3 ^a	7.5 ^b	7.5 ^{ab}	0.1	0.0039

P represents the significance level of the factor "Housing system" for ANOVA; different letters in the same raw indicate significant differences at $P \leq 0.05$ following LSD test.

Layer performances. Our data were in contrast with several authors that found a better production in cage than in barn system. *Voslarova et al. (2006)* ascribed this fact to some eggs being mislaid outside the nests in the barn system. In addition, mislaid eggs are often damaged and broken and the number of laying hens is also decreased as a consequence of the higher incidence of mortality in the deep litter system. As expected, in the present study the second category eggs (dirty, misshapen or broken eggs) that are discarded during collection were higher in organic and barn than in cage system (4.6% O, 4.3% B, 3.8% C; $P < 0.05$), however the mortality was the highest in cage. Some authors (*De Boer and Cornelissen, 2002; Petermann, 2003; Tauson, 2005*), documented in their studies that the replacement of traditional battery cage systems by alternative systems does not always have a positive impact on egg production, hen health and incidence of mortality. Accordingly, the LayWel database (*LayWel, 2006*) showed more dirty eggs in non cage systems, however this seemed to depend on the inclusion of floor eggs in the computation (*Rossi and De Reu, 2011*). Actually, *De Reu et al. (2009)* showed that the frequency of dirty eggs in nests of non-cage systems is not any higher than observed in cage systems.

The mortality observed in the present study for cage system was 6.8%, similar to the average value reported by *Hammershøj (2011)* for the 2008 Danish battery cages (6%). Surprisingly, lower mortality levels were obtained for organic and barn systems (2.4 and 4.2%, respectively). Differently, several authors reported that the incidence of mortality was greater in floor-reared laying hens than in laying hens reared in conventional cages (*Weitzenburger et al., 2005; Hammershøj, 2011*). The low levels of mortality observed in the present study are probably due to the high management level, good prevention practices and good health of animals. In fact, *Tauson et al. (1999)*, studying the mortality in cages compared

with aviary systems, detected higher levels of mortality (21 - 27%), caused mainly by bacterial infections due to pecking at naked skin by more aggressive laying hens.

Feed conversion rate (FCR) showed a value of 2.13 in cage system, lower than barn and organic values (2.20 and 2.30, respectively).

Usually FCR increases due to higher movement level in birds in systems with more activity, like organic and barn systems, in comparison to conventional cages (*Tauson et al., 1999; Michel and Huonnic, 2003*) but also due to higher heat lost in relation to feather cover and environmental temperature (*Peguri and Coon, 1993*).

Egg weight and eggshell characteristics. Considering the F values (data not shown), hen age had a great effect on all the variables, with major influence on egg weight, shell index, cracked eggs, shell percentage, displacement and energy in the compression test; the housing system was also important for the majority of variables but at levels lower than hen age. Housing system instead was the most influent factor for egg surface area, shell thickness and breaking strength. Differently, S x A interactions, even if significant, had minor effects.

Heavier eggs in barn system were observed also by *Pavlovski et al. (1981), Hughes et al. (1985)* and *Voslarova et al. (2005)*; similarly, *Vits et al. (2005)* reported a higher egg weight in floor-reared laying hens. However, several authors reported a higher egg weight in cage system (*Mohan et al., 1991; Pavlovski et al., 1994a, 1994b, 2001*) and other researchers demonstrated no effect of housing system on egg weight (*Mostert et al., 1995; Van den Brand et al., 2004*).

In agreement with the lowest occurrence of cracked eggs, organic eggs showed the highest shell percentage, the highest shell thickness and the most resistant shell, as expressed by their strength and energy values.

In accordance to our results, *Leyendecker et al. (2001b)* observed thicker shells in free range eggs in a study including also cage and aviary (barn) systems, and *Mohan et al. (1991)* evidenced a thicker shell in cage eggs compared to deep-litter housing. Differently, *Pavlovski et al. (2001)*, analysing eggs from three different systems including cage, detected thicker shells in barn eggs and thinner shells in free range eggs.

Egg weight and egg surface area increased with layer age in all housing systems (Table 3), following the physiological development of the animals, as reported by different authors (*Hill and Hall, 1980; O'Sullivan et al., 1991; Peebles et al., 2000; Silversides and Scott, 2001; Van den Brand, 2004; Rizzi and Chiericato, 2005*).

Shell thickness and percentage as well as shell index, shell strength, displacement and energy of the compression test followed a common trend during the production cycle: they initially increased until the layers were 43-weeks-old, and then decreased reaching, at 68 wk, values generally lower than those of young hens (27 wk). These results agree with the sudden increase of cracked eggs

percentage at the end of the laying cycle. However, the common trend observed reflects mainly the fluctuation in the response variables evidenced when data are plotted on separate curves for the three housing systems. In fact, in Figure 2, almost steady breaking strength and shell thickness of cage eggs are observable as a function of hen age. On the contrary it is evident that the common trend described above was mainly due to the variations of non-cage eggs values, especially organic eggs.

Several authors observed a significant decrease of shell thickness with hen age (*Suk and Park, 2001; Rizzi and Chiericato, 2005*). A shell percentage decrease with age was reported by *Silversides and Scott (2001)*. *Rodriguez-Navarro et al. (2002)* attributed the low resistance of old hens shells to changes in structural properties of the eggshell associated with aging. However, *O'Sullivan et al. (1991)* and *Peebles et al. (2000)* found no clear effect of hen age on shell thickness and percentage. This inconsistency of the literature data are totally justified by our results, showing for instance completely different trends over hen aging for shell thickness of cage, organic and barn eggs (Figure 2).

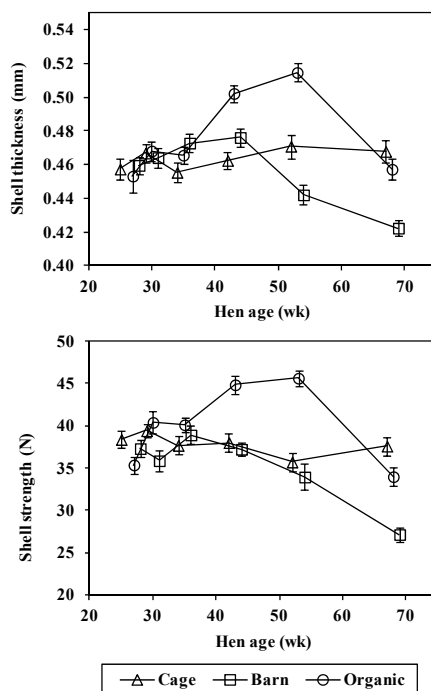


Figure 2: Shell strength and thickness of eggs from different housing systems throughout the complete hen laying cycle. Vertical bars represent the standard errors.

Bone strength. The differences among systems cannot be ascribed to the size of the bones, being the mean centre diameters very similar, although statistically different. In fact, no significant correlations were found between bone size and mechanical properties.

Several studies have shown a consistently higher incidence of bone fragility in caged laying hens compared to that of hens kept in alternative housing systems, mainly due to the limited opportunity to exercise (*Fleming et al., 1994; Van Niekerk and Reuvekamp, 1994; Leyendecker et al., 2001; Leyendecker et al., 2005*). In this research, only humeri of caged hens resulted weaker than those of hens reared in barn or organic systems. No significant differences in tibia breaking strength and stiffness were observed between cage and organic systems. Also previous studies comparing bone characteristics of hens reared in different housing systems reported significant differences in humeri mechanical indices and the lack of differences in tibiae properties (*Hughes et al., 1993; Abrahamsson and Tauson, 1997; Leyendecker et al., 2005*).

A great space availability and the presence of perches and sand baths increased humerus strength, probably because hens performed behaviours such as wing stretching, wing flapping, and sand bathing that have a positive effect on the bone mechanical properties (*Leyendecker et al., 2005*).

Conclusion

In conclusion the results suggested that the barn and the organic systems, as alternative systems to replace cage, showed layers performance similar to the cage system.

The study demonstrated that shell strength and thickness in non-cage eggs are highly affected by hen age, while they are much stable in cage eggs. Organic hens produce eggs with the most resistant shell and have the strongest humerus, while their tibiotarsus are as robust as those of cage hens.

Proizvodni rezultati, osobine ljuske i čvrstoća kostiju kokoši nosilja u tri različita sistema držanja

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Rezime

Cilj ovog istraživanja je bio da se utvrde efekti tri različita sistema držanja kokoši nosilje (u kavezima, živinarniku i organsko držanje) na proizvodne rezultate kokoši nosilja, osobine ljuske i čvrstoću kostiju. U svakom sistemu, korišćen je isti

hibrid nosilja (Hyline Braun ®) koje su bile smeštene u skladu sa trenutnim važećim evropskim propisom i kokoške su bile na istom nivou ishrane (2800 ME).

Istraživanje je sprovedeno u periodu od godinu dana na tri tipične farme na severu Italije, od 18. do 70. nedelje starosti kokoši. Broj jaja prikupljenih i izleženih na podu beležen je nedeljno, kao i mortalitet i potrošnja hrane. U 27, 30, 35, 43, 53 i 68 nedelji starosti nosilja, analizirani su težina i osobine ljuske jaja iz različitih sistema. Sila lomljena i čvrstoća su određivani testom tri tačke savijanja.

Procenat leženja je generalno veći u odnosu na standardnu proizvodnju Hyline nosilja, verovatno zbog visokog standarda upravljanja i proizvodne perzistencije. Rezultati su pokazali jasnu vezu između procenta ispucalih jaja i osobine čvrstoće ljuske, gde su organska jaja pokazala najveću debljinu ljuske, najotporniji ljusku i u skladu sa time manje slomljenih jaja. S obzirom na promene koje se dešavaju u toku ciklusa izlaganja, čvrstoća ljuske i debljina kod jaja koja ne potiču iz kavezne proizvodnje su pod snažnim uticajem starosti nosilja, dok su mnogo stabilniji kod jaja iz kaveza. Organske kokoši nosilje su takode imale najjači humerus, dok je njihov tibiotarsus bio robustan kao i kod kokoši nosilja iz kaveza.

References

- ABRAHAMSSON P., TAUSON R. (1997): Effects of group size on performance, health and birds' use of facilities in furnished cages for laying hens. *Acta Agriculturae Scandinavica*. 47:254-260.
- BARNETT J.L. (1998): The welfare and productivity of hens in barn system and cages: a report for the Rural Industries research and Development Corporation. 1998. RIRDC Project No DAV 112°.
- BUDGELL, K.L., SILVERSIDES F.G. (2004): Bone breakage in three strains of end of-lay hens. *Canadian Journal of Animal Science*, 84:745-747.
- CASIRAGHI E., HIDALGO A., ROSSI M. (2005): Influence of weight grade on shell characteristics of marketed hen eggs. In: *Proceedings of the 10th European symposium on the quality of eggs and egg products*, pp 83–188 (Doorwerth: WPSA).
- CLERICI F., CASIRAGHI E., HIDALGO A., ROSSI M. (2006): Evaluation of eggshell quality characteristics in relation to the housing system of laying hens. *Proc. XII European Poult. Conf.*, pp 1-6 (Verona, Italy).
- DE BOER I.J.M., CORNELISSEN A.M.G. (2002): A Method Using Sustainability Indicators to Compare Conventional and Animal-Friendly Egg Production Systems. *Poultry Science*. 81:173–181
- DE REU K., RODENBURG B., GREIJSPEERDT K., HEYNDRICKX M., TUYTTENS F., SONCK B., ZOONS J., HERMAN L. (2009): Bacteriological contamination, dirt and cracks of eggshells in furnished cages and non-cage

- systems for laying hens, an international on farm comparison. *Poultry Science*. 88: 2442-2448.
- DUNCAN I.J.H., FRASER D. (1997): Understanding animal welfare. In: APPLEBY M.C. & HUGHES B.O. (Eds.) *Animal welfare*. pp. 19–31 (Wallingford, UK, CABI Publishers).
- EU (1999) Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. OJ L203, 03/08/1999, p. 0053.
- EU (2007) Council Regulation (EC) No 834/2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. OJ L189, 1-23.
- FLEMING R.H., MCCORMACK H.A., MCTEIR H.A., WHITEHEAD C.C. (1996): The influence of medullary bone on humeral breaking strength. *British Poultry Science*. 37:30-32.
- FLEMING R.H., WHITEHEAD C.C., ALVEY D., GREGORY N.G., WILKINS L.J. (1994): Bone structure and breaking strength in laying hens housed in different husbandry conditions. *British Poultry Science*. 35:651-662.
- FREIRE L.J., WILKINS F., SHORT F., NICOL C.J. (2003): Behaviour and welfare of individual laying hens in a non-cage system. *British Poultry Science*. 44:22-29.
- GRAML C., WAIBLINGER S., NIEBUHR K. (2008): Validation of tests for on-farm assessment of the hen-human relation in non-cage systems. *Applied Animal Behaviour Science*. 111:301-310.
- GREGORY N.G., WILKINS L.J. (1989): Broken bones in domestic fowl: handling and processing damage in end-of lay battery hens. *British Poultry Science*. 30:555-562.
- GREGORY N.G., WILKINS L.J., ELEPERUMA S.D. (1990): Broken bones in domestic fowls: Effect of husbandry system and stunning method in end-of-lay hens. *British Poultry Science*. 31:59-69.
- GREGORY N.G., WILKINS L.J., KNOWLES T.G., SORENSEN P., VAN NIERKERK T. (1994): Incidence of bone fractures in European layers. In: Walker and Connell Proceedings of the Ninth European Poultry Conference Vol.2 (Glasgow, UK).
- HAMMERSHØJ M. (2011): Organic and free-range egg production. In: NYS Y., BAIN M., VAN IMMERSEEL F. (Eds.): *Improving the safety and quality of eggs and egg products*. Volume 1, pp 463-486 (Woodhead Publishing Limited, Cambridge, UK).
- HILLS A.T., HALL W. (1980): Effects of various combinations of oil spraying, washing, sanitizing, storage time, strain, and age of layer upon albumen quality changes in storage and minimum sample sizes required for their measurement. *Poultry Science*. 59:2237-2242.
- HUGHES B.O., DUN P., MCCORQUODALE C.C. (1985): Shell strength of eggs from medium-bodied hybrid hens housed in cages or on range in outside pens.

British Poultry Science. 26:129-136.

HUGHES B.O., WILSON S., APPLEBY M.C., SMITH S.F. (1993): Comparison of bone volume and strength as measures of skeletal integrity in caged laying hens with access to perches. *Research in Veterinary Science*. 54:202-206.

LAYWEL (2006): Work package 6 final report productivity and egg quality. Available from <http://www.laywel.eu>. Accessed March 2010.

LEESON S., DIAZ G., SUMMERS J.D. (1995): *Poultry Metabolic Disorders and Nycotoxins*, University Books, Guelph, Ontario, Canada.

LEYENDECKER M., HAMANN H., HARTUNG J. (2005): Keeping laying hens in furnished cages and an aviary housing system enhances their bone stability. *British Poultry Science*. 46:536-544.

LEYENDECKER M., HAMANN H., HARTUNG J., KAMPHENS J., RING C., GLUNDER G., AHLERS C., SANDER I., NEUMAN U., DISTL O. (2001): Analysis of genotype-environment interactions between layer lines and housing systems for performance traits, egg quality and bone breaking strength. 2nd communication: Egg quality traits. *Zuchtungskunde*. 73, 4:308-323.

MCCOY M.A., REILLY G.A.C., KILPATRICK, D.J. (1996): Density and breaking strength of bones of mortalities among caged layers. *Research in Veterinary Science*. 60:185-186.

MICHEL V., HUONNIC D. (2003): A comparison of welfare, health and production performance of laying hens reared in cages or in aviaries. *British Poultry Science*, 44/5:775-776.

MOHAN A., REDDY V.R., REDDY P.V., REDDY P.S. (1991): Utilization of pearl millet (*Pennisetum tynoides*) for egg production. *British Poultry Science*. 32:463-469.

MOSTERT B.E., BOWES E.H., VAN DER WALT J.C. (1995): Influence of different housing systems on the performance of hens of four laying strains. *Suid-Afrikaanse Tydskrif vir Veekunde*. 25:80-86.

NYS Y., BURLLOT T., DUNN I. C. (2008): Internal quality of eggs: any better, any worse? XXIII World's Poultry Congress, Brisbane, Australia, June 30-July 4, 2008, World's Poultry Science Association (Australian branch). 113. (CD-Rom (papers\\wpc08Final00034)).

PAVLOVSKI Z., HOPIĆ S., LUKIĆ M. (2001): Housing systems for layers and egg quality. *Biotechnology in Animal Husbandry*. 17:197-201.

PAVLOSKI Z., MASIC B., APOSTOLOV N. (1981): Quality of eggs laid by hens on free range and in cages. In: BEUVING, G., SHEELE, C.W. & SIMONS, P.C.M. (Eds) *Quality of Eggs*. Proceedings of the First European Symposium, pp. 231-235 (Apeldoorn, the Netherlands).

PAVLOVSKI Z., VRACAR S., MASIC B. (1994b): The effects of housing system on external egg quality traits in small flocks of layers. *Biotehnologija u Stočarstvu*. 10(3/4):13-19

PAVLOVSKI Z., HOPIC S., VRACAR S., MASIC B. (1994a): The effect of

housing system on internal egg quality traits in small layer flocks. *Biotehnologija u Stočarstvu*. 10(5/6):37-43

PEEBLES E.D., ZUMWALT C.D., DOYLE S.M., GERARD P.D., LATOUR M.A., BOYLE C.R., SMITH T.W. (2000): Effects of breeder age and dietary fat source and level on broiler hatching egg characteristics. *Poultry Science*. 79:698-704.

PEGURI A., COON C. (1993): Effect of feather coverage and temperature on layer performance. *Poultry Science*. 72:1318-1329.

PETERMAN S. (2003): Laying hens in alternative housing systems – practical experiences. *Dtsch. Tierarztl. Wochenschr.* 110:220–224

O'SULLIVAN N.P., DUNNINGTON E.A., SIEGEL P.B. (1991): Relationships among age of dam, egg components, embryo lipid transfer, and hatchability of broiler breeder eggs. *Poultry Science*. 70:2180–2185.

RIZZI C., CHIERICATO G.M. (2005): Organic farming production. Effect of age on the productive yield and egg quality of hens of two commercial hybrid lines and two local breeds. *Italian Journal of Animal Science*. 4:160-162.

RODRIGUEZ-NAVARRO A., KALIN O., NYS Y., GARCIA-RUIZ J.M. (2002): Influence of the microstructure on the shell strength of eggs laid by hens of different ages. *British Poultry Science*. 43:395–403.

ROSSI M., DE REU K. (2011): Alternative hen housing systems and egg quality. In: NYS Y., BAIN M., VAN IMMERSEEL F. (Eds.): *Improving the safety and quality of eggs and egg products*. Volume 1, pp 351-375 (Woodhead Publishing Limited, Cambridge, UK).

SANDILANDS V., SPARKS, N. WILSON S., NEVISON I. (2005): Laying hens at depopulation: the impact of the production system on bird welfare. *British Poultry Abstract*. 1:23-24.

SILVERSIDES F.G., SCOTT T.A. (2001): Effect of storage and layer age on quality of eggs from two lines of hens. *Poultry Science*. 80:1240-1245.

SUK Y., PARK C. (2001): Effects of broiler breeder age and length of egg storage on albumen characteristics and hatchability. *Poultry Science*. 80:855-858.

SUPIĆ B., PERIĆ L., MILOŠEVIĆ N., PAVLOVSKI Z., CMILJANIĆ R. (1999): Uticaj ishrane na kvalitet konzumnih jaja. *Savremena poljoprivreda*. 1-2:57-64.

TAUSON R. (2005): Management and housing systems for layers – effects on welfare and production. *Worlds Poultry Science Journal*. 61:477–490.

TAUSON R., ABRAHAMSSON P. (1994): Effects on production, health and behaviour in three SCWL strains in an EMC model in comparison with other modified and conventional cage. In: SHERWIN C.M. *Modified Cages for Laying Hens*, pp 41-54 (ed. Univ. Fed. Anim. Welf., Potters Bar, UK).

TAUSON R., WAHLSTROM A., ABRAHAMSSON P. (1999): Effect of two floor housing systems and cages on health, production and fear response in layers. *Journal Applied Poultry Research*. 8:152-159.

THOMPSON B.K., HAMILTON R.M.G., GRUNDER A.A. (1985): The

- relationship between laboratory measures of egg shell quality and breakage in commercial egg washing and candling equipment. *Poultry Science*. 64:901-909.
- TRAVEL A., NYS Y., BAIN M. (2011): Effects of hen age, moult, laying environment and egg storage on egg quality. In: NYS Y., BAIN M., VAN IMMERSSEEL F. (Eds): *Improving the safety and quality of eggs and egg products*. Volume 1, 300-329 (Woodhead Publishing Limited, Cambridge, UK).
- VAN DEN BRAND H., PARMENTIER H.K., KEMP B. (2004): Effects of housing system (outdoor vs cages) and age of laying hens on egg characteristics. *British Poultry Science*. 45:745-752.
- VAN NIEKERK T.G.M.C., REUVEKAMP B.F.J. (1994): Husbandry factors and bone strength in laying hens, in: *Proceedings of the 9th European Poultry Conference*. 133-136 (Glasgow, UK).
- VITS A., WEIZENBÜRGER HAMANN H., DISTL, O. (2005): Production, egg quality, bone strength, claw length, and keel bone deformities of laying hens housed in furnished cages with different group sizes. *Poultry Science*. 84:1511-1519.
- VOSLAROVA E., HANZALEK Z., VECEREK V., STRAKOVA E., SUCHY P. (2006): Comparison between laying hen performance in the cage system and the deep litter system on a diet free from animal protein. *Acta Veterinaria Brnensis*. 75:219-225.
- WEITZENBÜRGER D., VITS A., HAMANN H., DISTL O. (2005): Effect of furnished small group housing systems and furnished cages on mortality and causes of death in two layer strains. *British Poultry Science*. 46:553-559.
- WEBSTER A.B. (2004): Welfare implications of avian osteoporosis. *Poultry Science*. 83:184-192.
- WHITEHEAD C.C. (2004): Skeletal disorders in laying hens: the problem of osteoporosis and bone fractures in: PERRY G.C. (Ed.): *Welfare of laying hen*. *Poultry Science Symposium Series*. 27:259-278. Wallingford, Oxon: CABI Publishing.
- WILSON S., DUFF S.R.I., WHITEHEAD C.C. (1992): Effects of age, sex and housing on the trabecular bone of laying genetic group domestic fowl. *Research in Veterinary Science*. 50:52-58.