EGG QUALITY IN LAYERS HOUSED IN DIFFERENT PRODUCTION SYSTEMS AND SUBMITTED TO TWO ENVIRONMENTAL CONDITIONS

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ABSTRACT:
The production system using cages is a highly polemical issue in Europe, because of the space restriction imposed to laying hens. It is considered that the cage system might compromise important comfort movements, welfare and egg quality. This study evaluated egg quality and welfare of two strains of hens housed in a conventional system (battery laying cages) or litter system with nest and perches, and submitted to heat stress or comfort conditions. Two groups of 20 birds (10 Hy-line W36 and 10 Hy-line Brown) were submitted to two environmental conditions (26°C and 60% RH or 35°C and 70% RH) and two housing systems (cages or litter) in the early production phase. Egg quality was analyzed based on egg weight, eggshell thickness, specific gravity, and Haugh units. Yolk and shell contamination by *Salmonella sp* was also assessed. A significant ($p<0.05$) reduction in quality parameters was observed in eggs produced by laying hens under heat stress, mainly in the birds housed in cages.

Key Words: egg quality**,** environment, housing systems, laying hens

INTRODUCTION

In the past years, animal welfare laws have been issued in some European countries with strict guidelines concerning the available area per bird in cage rearing systems; in some cases, the use of cages has been forbidden. Therefore, some changes in the rearing system of laying hens in Brazil will probably be required in order to follow welfare guidelines of the European Union (European Commission - Directive 1999/74/CE). Furthermore, producers and consumers worldwide have been increasingly interested in production quality, since it is directly related to hygiene, health and mainly welfare of birds.

In the last decades, concerns related to animal comfort and welfare have increased notably, mainly when associated with physiological and behavioral responses (Silva, 2001).

New or “alternative” rearing systems have been proposed as substitutes for the currently used system (cage system). These include cage enrichment, integration of the cage with perches, nests and litter areas, or yet semi-confinement systems, in which there is a separate area for nests and litter.

Nevertheless, litter management in such systems is critical and the final quality of eggs might be affected. Excess of water in the litter results in wet feathers and feet and, consequently, dirty eggs. The final result is lower egg quality, since the eggs are not only dirty, but might also be contaminated (Elson, 1968).

It is well known that egg contamination starts on the farm, mainly because eggshells are contaminated with feces during laying or just after laying, or yet by contact with litter material, nests or even contaminated cages. Bacteria enter through eggshell pores and multiply within eggs (Souza *et al*., 2002). According to Padron

(1990), *Salmonella* and other bacteria might move through the eggshell and egg membranes, contaminating the inner contents.

Many studies have assessed how egg quality might be affected by environmental parameters, such as temperature and relative humidity (Andrade *et al*., 1976; Pereira, 1991; Mashaly *et al*., 2004). In layers submitted to high temperatures, egg quality was affected and the weight of egg components decreased (Bennion & Warren, 1933). On the other hand, few studies have been carried out to assess the effects of the rearing system on egg quality parameters when the layers are exposed to comfort conditions or heat stress.

This study evaluated the influence of environmental conditions on quality and bacterial contamination of eggs from laying hens housed in two production systems.

MATERIAL AND METHODS

The trial was carried out in a climatic chamber at Núcleo de Pesquisa em Ambiência (NUPEA), Departamento de Engenharia Rural, ESALQ/USP, Piracicaba, Brazil.

Twenty layers of two strains (Hy-Line W36 and Hy-Line Brown) at the beginning of the production period (22 weeks) were housed in two different systems, according to the following treatments:

Treatment C1 – Rearing system with litter and nests

Treatment C2 – Cage rearing system

There were five layers of each strain per rearing system subjected to environmental conditions of comfort or thermal stress, according to the treatments A1 and A2 described below.

Treatment A1 – Constant temperature of 26°C ± 2°C and relative humidity of 60% ± 2% (thermal comfort);

Treatment A2 – Constant ambient temperature of 35°C ± 2°C and relative humidity of 70% ± 2% (thermal stress).

All birds were exposed to each environmental condition in the climatic chamber for 14 consecutive days (experimental period). Birds were gradually acclimatized for one week previously to the experimental period. Acclimatization was necessary for the birds to get used to the climatic chamber and to the environmental conditions to which they would be exposed, i.e., comfort or thermal stress. Thus, temperature and RH were gradually increased during adaptation until the desired conditions. In this sense, by the time of data collection the birds would have been already submitted and adapted to the proposed environmental conditions.

Table 1 shows the mean temperature and relative humidity values inside the room during the adaptation period. On the last day of the adaptation period, temperature and relative humidity were those required for the experimental period, as described above (treatments A1 and A2).

Table 1. Temperature and relative humidity means during the adaptation period

Environmental data

Dry-bulb temperature (Tdb) and relative humidity (RH) data were collected inside the climatic chamber using mini weather stations and data logger HOBO®. The stations were installed at heights of 1.70, 1.50 and 0.50 m from the floor. Readings were performed at 15 min intervals over 24 hours and a temperature graph was plotted.

The thermal comfort zone was determined based on the thermal comfort index (enthalpy), using the equation described by Villa Nova (1999 cited by Furlan, 2001):

$$H = 6,7 + 0,243 * Tbs + \left\{ \frac{UR}{100} * 10^{\frac{7,5*Tbs}{237,3+Tbs}} \right\}$$

Where: H = enthalpy (kcal/kg dry air); Tdb = dry-bulb ambient temperature (ºC) and RH = relative humidity (%).

Physiological measurements:

Physiological data were analyzed for all birds, environmental conditions and rearing systems:

Rectal temperature (RT) – a thermometer was inserted through the cloaca inside the rectum for at least 2 min. RT was measured at 2 pm once weekly for each environmental condition;

Respiratory frequency (RF) – RF was observed for 15 seconds and recorded. Measurement was performed at 2 pm once weekly for each environmental condition, according to Harrison & Biellier (1968).

Egg quality variables:

Egg production was evaluated throughout the experimental period (28 days) except for the acclimatization period. The following parameters were assessed:

Egg weight – Determined to the nearest 0.01g using a digital scale.

Specific gravity – Determined using saline solutions, according to Voisey & Hunt (1974). The sampled eggs were immersed into solutions with increasing concentration of salt. The specific gravity is similar to the density of the solution in which the egg floats.

Haugh units – After the eggs were weighed, they were broken on a flat glass surface. The height of the albumen was registered using a tripod micrometer (AMES S-6428). Egg weight (g) and albumen height (mm) were used to calculate the Haugh units according to Pardi (1977): $HU = 100\log(h + 7.57 - 1.7W^{0.37})$, where: h = albumen height (mm) and W = egg weight (g).

Eggshell thickness – Thickness was measured after removing the internal membranes of the eggshell. It was used a precision micrometer to the nearest 0.01mm (Mitutoyo Dial Thickness Gage). Three measurements were taken at the equatorial region of the shell and the mean was calculated.

Microbiological assessment – the presence of *Salmonella sp* in the yolk and eggshell was evaluated, as well as the presence of fecal coliforms.

Statistical analysis:

It was used a 2 x 2 x 2 factorial with 5 repetitions (each bird was considered to be an experimental unit). There were 2 environmental conditions (comfort and stress), 2 layer strains (Hy-Line W36 and Hy-Line Brown) and 2 rearing conditions (litter + nests and cages). Statistical analyses were carried out using a commercial package (SAS®, 1998), and the means were compared by the Tukey's test ($p<0.05$).

RESULTS AND DISCUSSION

Environmental data:

Enthalpy

Figures 1 and 2 show the behavior of enthalpy (kJ / kg dry air) under comfort and thermal stress conditions, as well as the range and upper and lower limits that are considered ideal for birds.

Figure 1 – Enthalpy inside climatic chamber under comfort condition (actual enthalpy). The range considered to be ideal for birds is indicated together with the upper and lower comfort limits

Figure 2 – Enthalpy inside climatic chamber under thermal stress (actual enthalpy). The range considered to be ideal for birds is indicated together with the upper and lower comfort limits

The difference between the evaluated environmental conditions might be seen in Figures 1 and 2. The mean values of energy in the dry air mass are within the limits considered to be comfortable (Figure 1). On the other hand, under thermal stress condition (Figure 2) enthalpy values are higher than the comfort limits, which characterizes a condition of heat stress.

Physiological measurements:

Figure 3 shows the mean rectal temperature (RT) at the two proposed ambient conditions (comfort and heat stress), as well as for the two strains (Hy-Line W36 and Hy-Line Brown) and the two rearing systems (litter + nest and cages).

Figure 3 – Rectal temperature (RT) according to the strain, environment and rearing system

There was a significant increase ($p<0.05$) in the rectal temperature of birds subjected to thermal stress conditions, independent of strain and rearing system (Figure 3 and Table 2), corroborating a previous report (Harrison & Biellier, 1968). In regard to the rearing system, the birds kept on litter showed lower rectal temperature compared to the caged birds (Table 2). This difference might have been due to the greater space available to the birds in the litter system, enabling air circulation and thermal changes between the birds and the environment.

Table 2. Rectal temperature means (RT) of the different strains according to the environment and rearing system

The respiratory frequency (RF) was also different between the two ambient conditions to which the birds have been subjected. Under comfort conditions, for example, RF in birds reared using the litter system was between 160 and 180 movements per minute, whereas RF was between 180 and 200 movements per minute in the caged birds. The respiratory frequency of birds under thermal stress was 260-280 movements per minute in the litter system and 300 and 320 movements per minute in the cage system.

Such results are in accordance with those reported by Harrison & Biellier (1968), who showed an inverse relationship between respiratory rate and heart rate. There was a tendency of increased respiratory rate and decreased heart rate under high temperatures, which would have a direct relationship with the acid-base balance in birds. According to Mueler (1966), in the beginning of the panting process, respiratory alkalosis also occurs, and this might be enough to reduce eggshell thickness up to 12%.

Egg quality variables

Egg production during the experimental period was 100%, i.e., all layers submitted to the two ambient conditions and the two rearing systems laid eggs. This high percentage is possibly because the experimental period was in the early laying period.

Egg quality decreased when the birds were submitted to heat stress. The means of quality variables may be seen in Table 3.

Table 3. Egg quality assessment

Egg weight: According to Table 3, egg weight decreased significantly ($p<0.05$) when the layers were submitted to heat stress conditions. These results corroborate previous reports (Huston *et al*., 1957; De Andrade *et al.*, 1976; Mashaly *et al*., 2004).

Mean differences in egg weight between the two environmental conditions (Table 3) were 5.1 g and 2.4 g for Hy-Line Brown layers reared in the litter and cage system, respectively. On the other hand, the mean reduction in egg weight of Hy-Line W36 birds reared in the litter and cage system was 3.6 g and 5.2 g, respectively.

Given the wide acceptance of Hy-Line W36 strain by the egg industry, it is worth noting that birds of this strain reared in cages and submitted to heat stress showed greater decrease in egg weight (5.2g). Therefore, farmers must monitor and control environmental conditions carefully, because the final quality of eggs will be directly influenced by the ambient in which the birds are kept.

Specific gravity: Table 3 showed a significant reduction ($p<0.05$) in the values of specific gravity according to the environmental conditions.

There was no strain effect on this variable within environment (comfort or heat stress), although Hy-Line W36 birds have shown lower specific gravity under heat stress and cage system.

Specific gravity is closely related to eggshell quality. According to Hamilton (1982), specific gravity increases together with eggshell thickness. This was also observed in the present study (Table 3).

Peebles & McDaniel (2004) considered 1.0800 of specific gravity as the threshold between poor or good eggshell quality. In the present study, it was observed that this threshold was shown in the two strains only when submitted to comfort environmental conditions.

Haugh units: The values of Haugh units were significantly different ($p<0.05$) between the two environments. Under heat stress, the value decreased significantly. This might have been due to the stress to which the birds had been subjected. This finding corroborates a previous report (Kirunda *et al.*, 2001), in which there was a decrease in the Haugh unit values after heat stress in comparison to the values before heat stress.

It is worth noting that even with lower mean Haugh unit values under heat stress, the eggs have been classified as good grade eggs according to international grading systems.

The good quality of albumen even under heat stress conditions might be related to the age of birds. These results are in agreement with Souza *et al*. (1994), who reported greater Haugh unit values in eggs from younger birds that were in the early laying period.

Eggshell thickness: There were significant differences ($p<0.05$) between strains, rearing systems (within heat stress) and environmental conditions (Table 3).

Eggshell thickness decreased markedly during heat stress. Mahmoud *et al.* (1996) suggested that this results from serum calcium unbalance. Under high temperatures, there is a decrease in calcium levels and eggshell formation is compromised.

According to Pereira (1991), heat stress decreases blood pH and, consequently, the blood levels of HCO_3 available for eggshell formation and ultimately results in poorer eggshell quality.

In regard to the evaluated rearing systems, significant differences were seen only under heat stress. In general, the cage rearing system showed greater decrease in the mean values of eggshell thickness, independent of strain, which reinforces the negative effects of this rearing system together with high environmental temperature.

Considering the evaluated strains, there were significant differences in eggshell thickness both for the comfort and the heat stress conditions. Nevertheless, the decrease was more pronounced in Hy-Line W36 birds reared in cages and subjected to heat stress.

Microbiological assessment

None of the factors evaluated affected *Salmonella sp* contamination, since this pathogen was not detected in eggshells and yolks.

It is known that *Salmonella* might spread rapidly in the environment either by cross-contamination or through the ventilation system (Cason *et al.*, 1994). In the case that a totally closed environment is used, such as in the present study (climatic chambers), the problem is even greater and the birds might be contaminated almost immediately. Therefore, it might be concluded that, if *Salmonella* contamination was not detected in one egg, the other eggs were also not contaminated.

The results of contamination by fecal coliforms are shown in Table 4. The occurrence of fecal coliforms was greater in eggshells from eggs laid in the nests, independent of the environment. Thus, it should be carefully considered how much safer the system of litter and nest might really be, as far as food safety issues are concerned.

Table 4. Contamination of eggshell and yolk by fecal coliforms

CONCLUSION

Egg quality (weight, specific gravity and Haugh units) decreased when the birds were submitted to thermal stress. Nevertheless, there were no effects of strains on the same parameters under comfort conditions. Eggshell thickness was affected by environment and rearing system. It is suggested that the rearing system and aspects such as environment and welfare must be considered because they might affect product quality.

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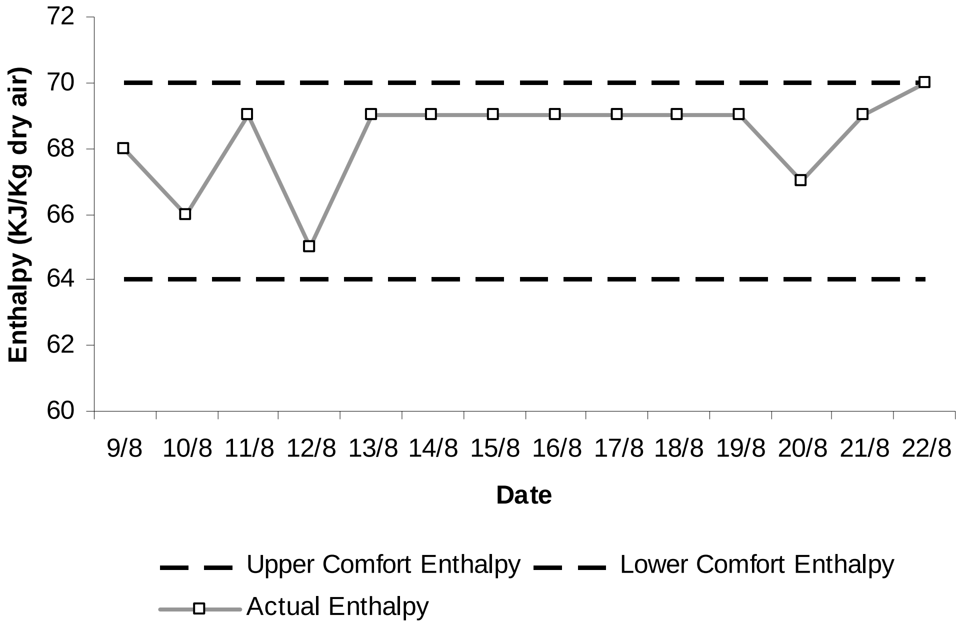

Figure 1 – Enthalpy inside climatic chamber under comfort condition (actual enthalpy). The range considered to be ideal for birds is indicated together with the upper and lower comfort limits

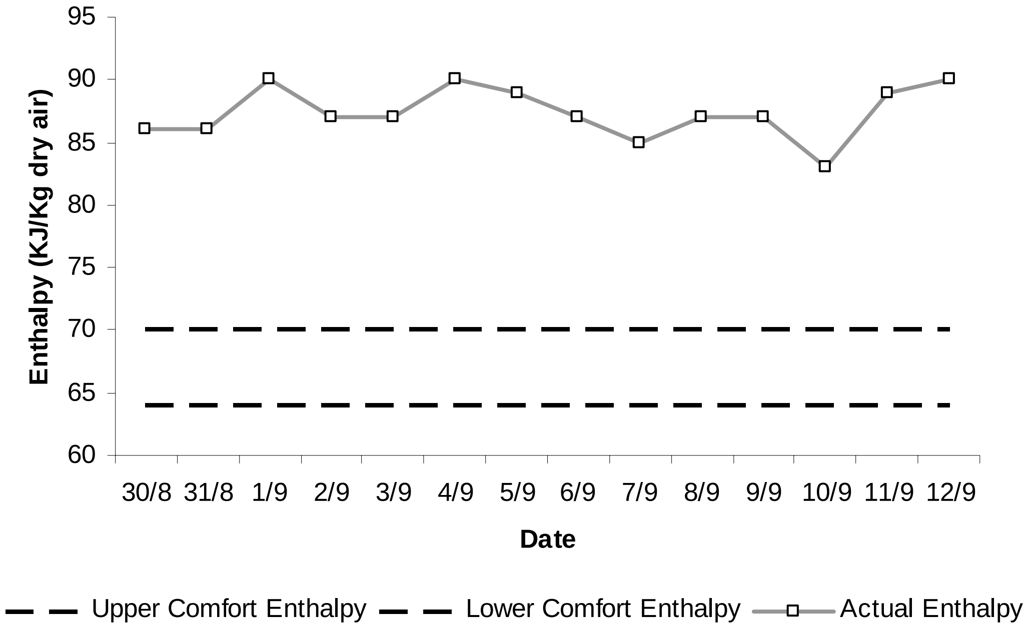

Figure 2 – Enthalpy inside climatic chamber under thermal stress (actual enthalpy). The range considered to be ideal for birds is indicated together with the upper and lower comfort limits

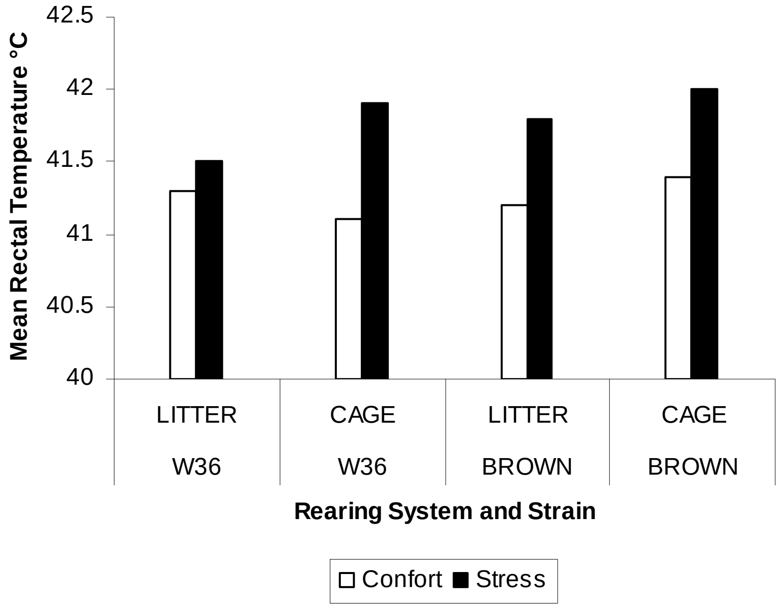

Figure 3 – Rectal temperature (RT) according to the strain, environment and rearing system

Table 1. Temperature and relative humidity means during the adaptation period

	Day	Mean Temp (°C)	Mean RH (%)
COMFORT	1	25	50
	2	25	50
	3	25	55
	4	25	55
	5	25	60
	6	26	60
	7	**26**	**60**
STRESS	1	26	60
	2	27	65
	3	29	66
	4	30	67
	5	32	68
	6	34	69
	7	**35**	**70**

Table 2. Rectal temperature means (RT) of the different strains according to the environment and rearing system

STRAIN	SYSTEM	RT	ENVIRONMENT	RT
W36	Litter	41.4 b	Confort	41.2 b
	Cage	41.5 b	Stress	41.7 a
BROWN	Litter	41.5 b	Confort	41.3 b
	Cage	41.7 a	Stress	41.8 b

[a,b] – means followed by similar letters within the column are not different by the Tukey's test ($p<0.05$).

Table 3. Egg quality assessment

			Egg quality variables			
			Weight (g)	Specific gravity	Haugh units	Shell thickness (mm)
Comfort	W36	Litter	55.5a	1.0917[a]	104.0a	0.458a
		Cage	54.7a	1.0912[a]	103.5a	0.451a
	Brown	Litter	57.8a	1.0902[a]	104.4a	0.435b
		Cage	55.5a	1.0897[a]	103.4a	0.432b
Stress	W36	Litter	51.9b	1.0775b	101.2b	0.400c
		Cage	49.5c	1.0772b	101.1b	0.383d
	Brown	Litter	52.7b	1.0777b	100.6b	0.410c
		Cage	53.1b	1.0774b	100.4b	0.368d

[a,b,c] – means followed by similar letters in the column are not different by the Tukey's test ($p<0.05$).

Table 4. Contamination of eggshell and yolk by fecal coliforms

Microbiological Characteristics				
Variable	**Local/Strain**	**Environment**	**Egg Part**	**Result**
Fecal Coliforms	Cage/W36	Comfort	Shell	Absence
			Yolk	Presence
	Cage/Brown	Comfort	Shell	Absence
			Yolk	Absence
	Nest/W36	Comfort	Shell	Presence
			Yolk	Absence
	Nest/Brown	Comfort	Shell	Presence
			Yolk	Absence
	Cage/W36	Stress	Shell	Absence
			Yolk	Absence
	Cage/Brown	Stress	Shell	Absence
			Yolk	Absence
	Nest/W36	Stress	Shell	Absence
			Yolk	Absence
	Nest/Brown	Stress	Shell	Presence
			Yolk	Absence