COMPARATIVE ANALYSIS OF EGG MASS AND INTERNAL STRUCTURE FROM DIFFERENT REARING SYSTEMS: ORGANIC, FREE-RANGE, BARN, AND CAGE HOUSING

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Abstract

Eggs represent one of the most valuable animal products for human nutrition, and their quality and composition are strongly influenced by the rearing system of laying hens. The present study aimed to evaluate the influence of different rearing systems on egg mass and internal structural components in Lohmann Brown-Classic laying hens. Egg samples were collected from four housing systems: organic, free-range, barn (intensive floor), and cage (intensive battery). Sampling was carried out three times per week, with eggs analyzed on the same day to avoid storage-related effects. A total of 288 consumer eggs were randomly selected throughout the experimental period.

Results indicated that eggs from the organic system recorded the highest average mass (63.49 g), followed by those from free-range hens (62.91 g). In contrast, eggs from intensive systems were lighter, with averages of 61.88 g (barn) and 61.21 g (cage). These findings suggest that increased freedom of movement positively influences egg productive parameters, with housing systems closer to natural conditions favoring improved egg development compared to intensive rearing.

Key words: *egg quality, free-range system, hen eggs, intensive system, rearing systems*

INTRODUCTION

In Romania, egg production has shown notable fluctuations in recent years. Giucă and Ilie (2021) reported a decline of about 12% in national egg production between 2016 and 2020, highlighting the growing dependence on imports to meet domestic demand [1]. At the same time, Gheorghe-Irimia et al. (2024) projected an upward trend in organic egg production, driven by consumer preferences and agricultural policies promoting sustainable practices [2]. These dynamics underline the need to evaluate different housing systems, from intensive to alternative, in terms of productivity, egg quality, and market adaptability.

The conventional battery-cage system, characterized by the confinement of a large number of hens in restricted spaces, has elicited considerable concern among consumers. Consequently, alternative housing systems such as furnished cages, deep-litter housing, free-range facilities, and cage-free rearing have become increasingly widespread in layer poultry production. Suboptimal management practices applied for laying hens may result in heat stress, nutritional imbalances, and metabolic disorders [3].

Multiple recent studies have examined the effect of housing systems on laying hens' performance, egg quality, and welfare. For example, Erek et al. (2024) found significant differences in egg production and welfare traits among hens reared in free-range, organic, and

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conventional intensive systems [4]. Rodriguez-Mengod et al. (2024) reported that eggs from organic systems exhibit improved shell quality and beneficial fatty acid profiles versus cage systems [5]. Studies such as Kawamura et al. (2023) emphasize that housing also influences less obvious traits, including eggshell lightness and free amino acid content of yolk and albumen [6]. While animal welfare considerations push for alternative systems, as noted in the comparison of aviary, barn, and conventional cage systems, trade-offs in productivity and feed efficiency must be considered. The use of enriched cages as compared to free-range systems, explored by Denlı et. al. (2016), may offer intermediate solutions for balancing welfare, quality, and economic viability [7].

Findings demonstrated that housing systems significantly affected egg production and quality, with enriched cages ensuring more consistent outputs, whereas free-range systems were associated with improved welfare conditions [7]. The housing system in which laying hens are kept can exert a significant influence on egg production performance [8]. The present analysis explores the relationship between housing systems and egg weight, as well as the weight of internal components.

MATERIAL AND METHOD

Study location and period

The study was conducted in two locations representative of the main laying hen production systems in Romania: a commercial poultry unit in Constanța County (organic, free-range, and intensive systems) and a commercial farm in Călărași County operating under an intensive system. This selection allowed the comparison of eggs originating from both alternative and intensive systems, under controlled and uncontrolled production conditions. The experiment was carried out over a period of 24 weeks in 2024.

Biological material

The study used laying hens of the Lohmann Brown-Classic hybrid, recognized for its high adaptability to different rearing systems and superior zootechnical performance. Birds of this hybrid are characterized by early onset of laying (18–20 weeks of age), an annual production exceeding 300 eggs, and high feed conversion efficiency. The eggs produced are uniform, with brown shells, an average weight of 63–67 g, and high internal quality traits [9]

Experimental design and sample collection

Eggs were collected three times per week from each system, and analyses were performed on the same day to eliminate the effect of storage. In total, 288 samples (consumption eggs) were analyzed during the study, randomly selected at each visit.

At the beginning of the study (February 2024), the laying hens were between 35 and 37 weeks of age, and by the end of the experimental period (July 2024) they had reached 59 to 61 weeks. The flocks were selected to ensure comparable ages across systems, thereby reducing the influence of age as a confounding factor.

Sample analysis

The determination of total egg weight and the weight of internal components (yolk, albumen, and shell) was performed using the EggAnalyzer™ device, applying the integrated weighing function. Component separation was carried out by controlled breaking of the egg on a separator.

Statistical methods

Descriptive analysis involved calculating the arithmetic mean, standard deviation (SD), variance (Var), coefficient of variation (CV%), standard error of the mean (SEM), as well as minimum (Min) and maximum (Max) values. These parameters allowed characterization of the distribution and variability of data within each analyzed group.

RESULTS AND DISCUSSIONS

Total weight of the egg

The statistical analysis of the total weight of consumer eggs according to the exploitation system is found in Table 1. The highest mean values were recorded in the organic system (63.49 g), followed by eggs from the free-range system (62.91 g). In contrast, eggs from intensive systems exhibited lower weights, with averages of 61.88 g for the floor system and 61.21 g for the battery system. The difference between the two intensive systems was relatively small (≈0.67 g), however, compared with the organic system, a difference of more than 2 g was observed, indicating a clear tendency toward higher values in systems that provide greater freedom of movement. This observation is consistent with findings reported in the literature, where superior egg weights are frequently associated with extensive or alternative systems (free-range, backyard) compared with intensive ones. For instance, Kucukkoyuncu et al. (2017) reported average egg weights of 62.2–65.1 g in free-range systems, whereas eggs from intensive battery systems showed average weights ranging from 60.5 g to 64.4 g [10].

With regard to internal variability, the standard deviation showed higher values in eggs from the free-range system (2.908 g) and lower values in those from the battery-based intensive system (1.816 g), suggesting greater homogeneity in flocks originating from intensive farms. The same trend was confirmed by the variance values, which ranged from 3.297 in the battery system to 8.457 in the free-range system. The coefficient of variation ranged between 2.97% and 4.62%, relatively low values that reflect a generally good level of uniformity across all rearing systems. The lowest variability was observed in eggs from the battery-based intensive system (CV = 2.97%), while the highest variability was characteristic of eggs from the free-range system (CV = 4.62%). The standard error of the mean (SEM) ranged between 0.214 g (IB) and 0.343 g (FR), indicating high accuracy of mean estimates in all cases, with greater confidence in the intensive systems where flocks were more uniform.

Table 1. Descriptive statistics of the total weight of table eggs from different rearing systems (n = 72 per system)

Rearing systems	Min	Max	x̄ (Mean)	SD	Var	CV (%)	SEM
O	58.01	67.28	63.49	2.337	5.461	3.68	0.275
FR	57.09	66.91	62.91	2.908	8.457	4.62	0.343
IS	57.82	66.95	61.88	2.731	7.460	4.41	0.322
IB	58.36	64.88	61.21	1.816	3.297	2.97	0.214

Note: O - organic eggs; FR - free-range eggs; IS - intensive eggs - ground-based; IB - intensive eggs - battery-based; Min = minimum value; Max = maximum value; x̄ = mean; SD = standard deviation; Var. = variance; CV = coefficient of variation; SEM = standard error of the mean.

Yolk weight

The statistical analysis of yolk weight in table eggs according to the rearing system is presented in Table 2. The highest mean values were recorded in eggs from the organic system (18.13 g), followed by those obtained in the free-range system (17.81 g). In contrast, the lowest mean values were observed in the intensive systems: 17.21 g in the floor-based system and 16.91 g in the battery system.

The internal variability of the data was assessed using the standard deviation and coefficient of variation. The greatest fluctuations were observed in eggs from the free-range system (SD = 0.611 g, CV = 3.43%) and the organic system (SD = 0.570 g, CV = 3.14%), whereas eggs obtained from intensive systems exhibited higher uniformity, with lower standard deviations (SD = 0.400–0.439 g) and coefficients of variation ranging between 2.33% and

2.60%. The standard error of the mean (SEM) showed low values, ranging from 0.047 g (IS) to 0.072 g (FR), confirming good precision in the estimation of arithmetic means across all rearing systems.

The analysis of extreme values indicated a wider range of variation in eggs from organic (17.14–19.25 g) and free-range systems (16.42–18.75 g), compared with intensive systems, where the intervals were narrower (IS: 16.53–17.89 g; IB: 16.09–17.86 g).

Albumen weight

Table 3 presents the descriptive statistics of albumen weight in table eggs obtained from four rearing systems. The mean values of albumen weight ranged between 36.81 g (IB) and 37.27 g (O), indicating relatively low variation among systems. The organic (37.27 g) and free-range (37.22 g) systems recorded very similar values, slightly higher than those obtained in intensive systems. The lowest mean was observed in the battery-based intensive system (36.81 g).

Eggshell weight

The statistical interpretation of eggshell weight (Table 4) highlights that the highest mean values were obtained for eggs from the organic system (8.09 g), followed by those from the free-range system (7.88 g). The lowest values were recorded in the intensive systems, both floor-based (7.62 g) and battery-based (7.49 g). These results suggest that extensive systems tend to promote the development of heavier shells, whereas in intensive production systems, shell weight is reduced.

Table 2. Descriptive statistics of yolk weight of table eggs from different rearing systems (n = 72 per system)

Rearing systems	Min	Max	x̄ (Mean)	SD	Var	CV (%)	SEM
O	17.14	19.25	18.13	0.570	0.324	3.14	0.067
FR	16.42	18.75	17.81	0.611	0.374	3.43	0.072
IS	16.53	17.89	17.21	0.400	0.160	2.33	0.047
IB	16.09	17.86	16.91	0.439	0.193	2.60	0.052

Note: O - organic eggs; FR - free-range eggs; IS - intensive eggs - ground-based; IB - intensive eggs - battery-based; Min = minimum value; Max = maximum value; x̄ = mean; SD = standard deviation; Var. = variance; CV = coefficient of variation; SEM = standard error of the mean.

Table 3. Descriptive statistics of albumen weight of table eggs from different rearing systems (n = 72 per system)

Rearing systems	Min	Max	x̄ (Mean)	SD	Var	CV (%)	SEM
O	35.23	39.23	37.27	0.981	0.961	2.631	0.116
FR	35.16	39.16	37.22	0.968	0.937	2.601	0.114
IS	35.05	39.05	37.05	1.012	1.023	2.730	0.119
IB	34.69	38.69	36.81	0.963	0.927	2.615	0.113

Note: O - organic eggs; FR - free-range eggs; IS - intensive eggs - ground-based; IB - intensive eggs - battery-based; Min = minimum value; Max = maximum value; x̄ = mean; SD = standard deviation; Var. = variance; CV = coefficient of variation; SEM = standard error of the mean.

Table 4. Descriptive statistics of eggshell weight of table eggs from different rearing systems (n = 72 per system)

Rearing systems	Min	Max	x̄ (Mean)	SD	Var	CV (%)	SEM
O	7.61	8.65	8.09	0.224	0.050	2.772	0.026
FR	7.23	8.50	7.88	0.253	0.064	3.208	0.030
IS	7.24	8.32	7.62	0.220	0.048	2.883	0.026
IB	6.79	8.07	7.49	0.272	0.074	3.636	0.032

Note: O - organic eggs; FR - free-range eggs; IS - intensive eggs - ground-based; IB - intensive eggs - battery-based; Min = minimum value; Max = maximum value; x̄ = mean; SD = standard deviation; Var. = variance; CV = coefficient of variation; SEM = standard error of the mean.

CONCLUSIONS

The minimum egg weights ranged from 57.09 g (FR) to 58.36 g (IB), while the maximum values ranged from 64.88 g (IB) to 67.28 g (O). These data indicate that eggs from extensive systems tend to reach higher maximum values and display a wider range of variation, whereas eggs obtained in battery systems are characterized by greater uniformity and a narrower variation range.

A general trend can be noted whereby eggs from alternative systems (O and FR) exhibited slightly heavier yolk and albumen compared with those from intensive systems (IS and IB), which may be associated with nutritional and behavioral factors specific to hens reared in larger spaces. Overall, the findings indicate that organic and free-range systems favor a higher eggshell mass, while intensive farms, despite their high level of uniformity and control, produce eggs with lighter shells.

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