THE INFLUENCE OF SEASON AND STOCKING DENSITY ON MEAT QUALITY IN BROILER CHICKENS

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Abstract

To assess the influence of season and stocking density on meat quality in Ross-308 chickens, two experiments were conducted (one in December-January and the other in July-August), each with three groups differentiated by stocking density (19 birds/m² = Lc-1 and Lc-2; 17 birds/m² = Lexp-1 and Lexp-3; 16 birds/m² = Lexp-2 and Lexp-4). In the warm season, the pH of the meat showed narrower ranges between measurements on warm meat (6.70-6.76) and refrigerated meat (6.03-6.11), compared to the values found in the cold season (6.75-6.80 vs. 6.11-6.18). The sensory qualities of the meat were influenced by stocking density, with lower densities receiving higher scores. However, the scores in the warm season were lower than those in the cold season. Compared to the chickens reared at higher densities, those housed at the 16 birds/m² stocking rate had the highest dry matter content (0.60-0.71% higher in the cold season and 0.65-0.71% higher in the warm season), protein content (0.41-0.55% and 0.54-0.62% higher, respectively), and lipid content (0.10-0.11% and 0.13-0.17% higher, respectively). In conclusion, to maintain meat quality within normal limits during periods of extreme temperatures, lower stocking densities should be applied.

Key words: *broiler, density, season, meat quality.*

INTRODUCTION

The current welfare standards applied at the European Union level [1] ensure a higher quality of life for birds [2], respect the views of those concerned with animal protection [3], and protect the environment [4]. Bird welfare is associated with population density [5, 6], but some authors argue that it is influenced by current nutritional practices aimed at optimizing productive efficiency [7]. Others claim it depends on the individual's ability to cope with social structures and management practices [8], while some emphasize that meat chicks require a wide range of needs to ensure their welfare [9].

Although various methodologies for assessing bird welfare have been developed [10], problems generated by other factors continue to be identified in order to ensure their well-being until they are slaughtered [11]. On the other hand, it is well-known that compliance with such standards in meat poultry production [12, 13] leads to a reduction in the economic efficiency of the units [14]. According to Romanian legislation, farmers can access EU payments to compensate for losses incurred due to compliance with welfare standards, with the obligation to reduce density by 10% or 15%, as well as emissions by 30% compared to the minimum mandatory requirements [15]. Another specific aspect

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of meat poultry farms is that the performance achieved (slaughter weight, feed conversion ratio, and mortality) is influenced not only by density but also by the living conditions provided during growth [16,17].

In the specific climatic conditions of our country, there are significant technical and economic differences from one season to another, as creating a microclimate compatible with physiological requirements incurs additional costs during extreme periods [18, 19]. Based on these considerations, we aimed to study the effects of population density and the growing season (season) on the quality parameters of the meat obtained from intensively raised broiler chickens.

MATERIAL AND METHOD

To achieve our proposed goal, two experiments were conducted (one in the cold season: December-January; one in the warm season: July-August), each consisting of three experimental groups differentiated by population density as follows: groups Lc-1 and Lc-2=19 birds/m²; groups Lexp-1 and Lexp-3=17 birds/m²; groups Lexp-2 and Lexp-4=16 birds/m². The biological material used was the Ross-308 broiler chicken, raised in an intensive system in production halls (one per group) identical in size (usable area = 1190 m²) and technical equipment, utilizing compound feeds with the same nutritional characteristics.

The chickens were slaughtered on the 35th day, at which point samples from the pectoral muscle (five birds per group) were collected for specific analyses.

Meat quality was assessed based on pH value, sensory properties, and chemical composition, in accordance with accredited methods:

- *pH value:* an electronic pH meter was used, allowing direct reading of acidity in the working suspension (SR ISO 2917:2007);
- *Sensory properties:* were evaluated by comparison with the conditions outlined in specific standards (ISO 8589: 1998), using samples of pectoral muscle subjected to thermal processing (maintained for 20 minutes at +120ºC to achieve +70ºC at the thermal center);
- *Water content*: the drying method in an oven was applied, exposing the sample to a heat source until the weight of the residue became constant (SR ISO 936:2009; SR ISO 1442:2010), calculated using the following relation:

$$H_2o\ (\%) = \frac{m_1}{m_2} \times 100$$

m_2 = final sample weight (g);
m_1= initial sample weight (g).

- content in dry matter - with the relationship:
  S.U. (%) = 100 - % H_2O
- protein content - by the Kjeldahl method (SR EN ISO 937:2007):

$$\text{Protein substances } (\%) = \frac{0{,}0014 \times 2\ (v_1 - \frac{V_2}{2} \times f) \times 6{,}26}{M} \times 100$$

v_1 = volume of H_3BO_3 4% inserted into the collecting cup (mL) (25mL);
v_2 = volume of H_2SO_4 0,1N using at titration (mL);
f = the solution factor de H_2SO_4 (1,1);
m = sample weight (g).

- the lipid content - the extraction was carried out with the help of organic solvents, by the Soxhlet method (SR ISO 1444: 2008), and at the end the formula was applied:

$$Gr\ (\%) = \frac{m_2 - m_1}{m} \times 100$$

m = sample weight (g SU);
m_2 = final weight of the extraction vessel (g);
m_1 = initial weight of the extraction vessel (g).

- ash content - by the calcination method (SR ISO 936:2009) and the following calculation relationship:

$$\text{Ash content } (\%) = \frac{m_2 - m_1}{m} \times 100$$

m = sample weight (g);
m_2 = crucible weight+ash (g);
m_1 = empty crucible weight (g).

The data were statistically processed, calculating the arithmetic mean, standard error of the mean, and coefficient of variation, as well as the significance of the differences between the means.

RESULTS

pH Value: In broilers raised during the cold season, the pH of the meat ranged from 6.75 to 6.80 for fresh meat and between 6.11 and 6.18 for meat refrigerated for 24 hours (Table 1).

In the warm season, the high temperatures during the transportation of the birds led to closer pH values between the measurements taken on hot meat and those taken on refrigerated meat (Table 2).

Sensory Properties: The meat obtained in the cold season from broilers raised at the lowest density received higher scores for three sensory attributes, while the meat from broilers raised at the highest density scored higher for juiciness (Table 3). The same phenomenon was observed in broilers raised during the warm season, with the note that the scores given were lower than those in the cold season (Table 4).

Chemical Composition: The meat from broilers raised at a density of 16 birds/m² was characterized by a higher dry matter content (27.09% in the cold season and only 26.93% in the warm season), which was 0.60-0.71% and 0.65-0.71% higher, respectively, compared to the groups with densities of 17 and 19 birds/m². The same group also exhibited a higher protein content (by 0.41-0.55% and 0.54-0.62%, respectively) as well as a higher lipid content (by 0.10-0.11% and 0.13-0.17%) compared to the other groups (Tables 5 and 6).

DISCUSSIONS

The raising of broiler chickens incurs somewhat higher costs during the cold season, but it is easier to ensure a favorable microclimate, so the productivity indicators are better than in the warm season, and the meat quality remains within normal limits; in the warm season, very high temperatures negatively affect the chickens' metabolic processes, which impacts growth performance and meat quality [20].

pH Value: Under normal conditions, the pH of poultry meat is 7.1-7.2 immediately after slaughter, decreases to 5.4-5.6 over the next 12-24 hours, and then stabilizes between 5.6-5.8 during storage; deviations occur when transport to the slaughterhouse is at too high a density, when the birds are ill, or due to extreme temperatures [20].

For the meat obtained from chickens raised in the *cold season*, the pH value immediately after slaughter (fresh meat) was 6.80 for the Lc-1 group (19 birds/m²), 6.78 for the Lexp-1 group (17 birds/m²), and 6.75 for the Lexp-2 group (16 birds/m²), with no statistically significant differences between the groups. The next evaluation was carried out on meat refrigerated for 24 hours, in which case the pH levels were lower than in the previous case, registering 6.18 for the Lc-1 group, 6.15 for the Lexp-1 group, and 6.11 for the Lexp-2 group; the differences between the groups were not statistically significant (Table 1).

Table 1 The pH value of meat in broiler chickens reared in the cold season

Specification	Batch	Statistical estimators (n=10)		
		$\overline{X} \pm s_{\overline{x}}$	V%	The meaning of the differences
Fresh meat	Lc-1	6.80±0.032	5.22	Lc-1 vs Lexp-1: p = 0.8089
	Lexp-1	6.78±0.077	3.87	Lc-1 vs Lexp-2: p = 0.7248
	Lexp-2	6.75±0.071	3.59	Lexp-1 vs Lexp-2: p = 0.7922
Refrigerated meat	Lc-1	6.18±0.118	6.02	Lc-1 vs Lexp-1: p = 0.8240
	Lexp-1	6.15±0.097	4.98	Lc-1 vs Lexp-2: p = 0.8111
	Lexp-2	6.11±0.081	4.17	Lexp-1 vs Lexp-2: p = 0.8397

* significant differences (0,01 < p < 0,05); ** distinctly significant differences (0,001 < p < 0,01); *** very significant differences (p < 0,001).

For chickens raised in the *warm season*, pH measurements on fresh meat showed values of 6.76 for the Lc-2 group, 6.72 for the Lexp-3 group, and 6.70 for the Lexp-4 group, but again, the differences between the three groups were not statistically significant.

For the meat refrigerated for 24 hours, the pH values ranged between 6.03 (Lexp-4 group) and 6.11 (Lc-2 group), with an intermediate value of 6.05 for the Lexp-3 group. No statistically significant differences were found between the groups (Table 2).

Table 2 Meat pH value in broiler chickens raised in the warm season

Specification	Batch	Statistical estimators (n=10)		
		$\bar{X} \pm s_{\bar{x}}$	V%	The meaning of the differences
Fresh meat	Lc-2	6.76±0.187	8.72	Lc-2 vs Lexp-3: p = 0.8877
	Lexp-3	6.72±0.169	7.98	Lc-2 vs Lexp-4: p = 0.8898
	Lexp-4	6.70±0.151	7.13	Lexp-3 vs Lexp-4: p = 0.8954
Refrigerated meat	Lc-2	6.11±0.176	9.09	Lc-2 vs Lexp-3: p = 0.9241
	Lexp-3	6.05±0.158	8.25	Lc-2 vs Lexp-4: p = 0.9437
	Lexp-4	6.03±0.152	7.99	Lexp-3 vs Lexp-4: p = 0.9772

* significant differences (0,01 < p < 0,05); ** distinctly significant differences (0,001 < p < 0,01); *** very significant differences (p < 0,001).

In chickens raised at high density (13 birds/m²), neither the conversion rate nor certain meat characteristics (color, shear force, and cooking loss), nor the pH, were affected compared to those raised at low density (6 birds/m²) [21]. For chickens raised in free-range systems, the pH value was only 5.75, lower than that of chickens raised in industrial systems, due to more intense physical activity during the growth phase [22].

Sensory characteristics: For the meat from chickens raised in the *cold season*, the most appreciated attribute was tenderness, with scores ranging from 4.79 (Lc-1 group) to 4.86 (Lexp-1 group), followed by firmness, which received scores between 4.60 (Lc-1) and 4.66 (Lexp-2). Scores for the flavor + taste attribute ranged from 4.20 (Lc-1) to 4.29 (Lexp-2), and for juiciness, between 4.11 (Lexp-1) and 4.15 (Lc-1 and Lexp-2 groups). There were no statistically significant differences between the groups for any of the sensory attributes analyzed (Table 3).

Table 3 Meat sensory parameters in broiler chickens reared in the cold season

Parameters	Batch	Statistical estimators (n=10)		
		$\bar{X} \pm s_{\bar{x}}$	V%	The meaning of the differences
Tenderness	Lc-1	4.79±0.10	6.59	Lc-1 vs Lexp-1: p = 0.9224
	Lexp-1	4.83±0.09	5.81	Lc-1 vs Lexp-2: p = 0.9118
	Lexp-2	4.86±0.05	3.12	Lexp-1 vs Lexp-2: p = 0.9417
Succulence	Lc-1	4.15±0.06	4.88	Lc-1 vs Lexp-1: p =0.9098
	Lexp-1	4.11±0.05	3.65	Lc-1 vs Lexp-2: p = 0.9998
	Lexp-2	4.15±0.08	6.18	Lexp-1 vs Lexp-2: p = 0.9097
Aroma + flavor	Lc-1	4.20±0.08	6.12	Lc-1 vs Lexp-1: p =0.8785
	Lexp-1	4.25±0.08	5.99	Lc-1 vs Lexp-2: p = 0.8549
	Lexp-2	4.29±0.06	4.76	Lexp-1 vs Lexp-2: p = 0.8754
Consistency	Lc-1	4.60±0.10	6.82	Lc-1 vs Lexp-1: p = 0.8544
	Lexp-1	4.64±0.10	7.05	Lc-1 vs Lexp-2: p = 0.8497
	Lexp-2	4.66±0.09	6.19	Lexp-1 vs Lexp-2: p = 0.8862

* significant differences (0,01 < p < 0,05); ** distinctly significant differences (0,001 < p < 0,01); *** very significant differences (p < 0,001).

Examination of the meat from chickens raised in the *warm season* revealed scores between 4.74 (Lc-2 group) and 4.82 (Lexp-4 group) for tenderness, between 4.11 (Lexp-4) and 4.19 (Lc-2) for juiciness, between 4.20 (Lc-2) and 4.26 (Lexp-4) for flavor + taste, and between 4.56 (Lc-2) and 4.63 (Lexp-4) for firmness. In all analyzed cases, the value differences between the groups were not statistically significant (Table 4).

Table 4 Sensory parameters of meat in broiler chickens raised in the warm season

Parameters	Batch	Statistical estimators (n=10)		
		$\bar{X} \pm s_{\bar{x}}$	V%	The meaning of the differences
Tenderness	Lc-2	4.74±0.122	8.16	Lc-2 vs Lexp-3: p = 0.8574
	Lexp-3	4.80±0.121	7.94	Lc-2 vs Lexp-4: p = 0.8762
	Lexp-4	4.82±0.112	7.32	Lexp-3 vs Lexp-4: p = 0.9008
Succulence	Lc-2	4.19±0.088	6.63	Lc-2 vs Lexp-3: p = 0.8311
	Lexp-3	4.13±0.086	6.58	Lc-2 vs Lexp-4: p = 0.8349
	Lexp-4	4.11±0.070	5.38	Lexp-3 vs Lexp-4: p = 0.8989
Aroma + flavor	Lc-2	4.20±0.106	7.98	Lc-2 vs Lexp-3: p = 0.8412
	Lexp-3	4.25±0.102	7.62	Lc-2 vs Lexp-4: p = 0.8448
	Lexp-4	4.26±0.096	7.12	Lexp-3 vs Lexp-4: p = 0.8999
Consistency	Lc-2	4.56±0.116	8.03	Lc-2 vs Lexp-3: p = 0.8576
	Lexp-3	4.61±0.113	7.77	Lc-2 vs Lexp-4: p = 0.8597
	Lexp-4	4.63±0.101	6.91	Lexp-3 vs Lexp-4: p = 0.8897

* significant differences (0,01 < p < 0,05); ** distinctly significant differences (0,001 < p < 0,01); *** very significant differences (p < 0,001).

The results of the sensory panel applied to the pectoral muscle of chickens raised in different systems (organic, free-range, and conventional) indicated that the meat was more tender (P<0.05) and easier to chew (P<0.05) in conventionally raised chickens, but there were no differences for other sensory properties [23].

Evaluation of the technological properties (color, water retention capacity, drip loss, cooking loss, and shear force) in Hubbard chickens slaughtered at different ages showed that the most significant statistical differences occurred between chickens slaughtered at 56 and 84 days [24].

Chemical Composition: Analyses conducted on the meat of chickens raised in the *cold season* indicated a water content of 73.62±2.28% in the Lc-1 group, 73.51±2.10% in the Lexp-1 group, and only 72.91±2.02% in the Lexp-2 group, with the remaining percentage up to 100% being represented by dry matter.

For protein content, the best results were observed in the Lexp-2 group (23.28±0.55%), followed by Lexp-1 (22.87±0.35%) and Lc-1 (22.73±0.38%), a trend also seen for lipid content, with values of 1.80±0.024%, 1.70±0.026%, and 1.69±0.027%, respectively.

Ash content was found to range between 1.21±0.029% (Lc-1 group) and 1.24±0.035% (Lexp-2 group), while the content of nitrogen-free extract substances (NFE) ranged from 0.70±0.010% (Lexp-1) to 0.77±0.004% (Lexp-2). Statistically significant differences were identified between the Lexp-2 group and the Lc-1 and Lexp-1 groups for water content, dry matter content, and protein content (show Table 5).

Table 5 Chemical composition of meat in broiler chickens raised in the cold season

Parameters	Batch	Statistical estimators (n=10)		
		$\overline{X} \pm s_{\overline{x}}$	V%	The meaning of the differences
Water (%)	Lc-1	73.62±2.28	9.79	Lc-1 vs Lexp-1: p = 0.7649
	Lexp-1	73.51±2.10	9.04	* Lc-1 vs Lexp-2: p = 0.0363
	Lexp-2	72.91±2.02	8.75	* Lexp-1 vs Lexp-2: p = 0.0358
Dry substance (%)	Lc-1	26.38±0.83	9.95	Lc-1 vs Lexp-1: p = 0.7366
	Lexp-1	26.49±0.81	9.69	* Lc-1 vs Lexp-2:p = 0.0322
	Lexp-2	27.09±0.79	9.17	* Lexp-1 vs Lexp-2: p = 0.0319
Protein (%)	Lc-1	22.73±0.38	5.22	Lc-1 vs Lexp-1: p = 0.7887
	Lexp-1	22.87±0.35	4.78	* Lc-1 vs Lexp-2: p = 0.0424
	Lexp-2	23.28±0.55	7.42	* Lexp-1 vs Lexp-2: p = 0.0419
Fat (%)	Lc-1	1.69±0.027	5.09	Lc-1 vs Lexp-1: p = 0.9527
	Lexp-1	1.70±0.026	4.87	Lc-1 vs Lexp-2: p = 0.9411
	Lexp-2	1.80±0.024	4.13	Lexp-1 vs Lexp-2: p = 0.9475
Ash (%)	Lc-1	1.21±0.029	7.56	Lc-1 vs Lexp-1: p =0.9568
	Lexp-1	1.22±0.027	6.99	Lc-1 vs Lexp-2: p = 0.9499
	Lexp-2	1.24±0.035	8.89	Lexp-1 vs Lexp-2: p = 0.9524
SEN (%)	Lc-1	0.75±0.008	3.33	Lc-1 vs Lexp-1: p =0.8781
	Lexp-1	0.70±0.010	4.18	Lc-1 vs Lexp-2: p = 0.8626
	Lexp-2	0.77±0.004	1.86	Lexp-1 vs Lexp-2: p = 0.8799

* significant differences (0,01 < p < 0,05); ** distinctly significant differences (0,001 < p < 0,01); *** very significant differences (p < 0,001).

In the *warm season*, the meat of chickens in the Lc-2 group had a dry matter content of 26.22±0.74%, of which 22.44±0.51% were proteins, 1.78±0.044% lipids, 1.20±0.016% ash, and 0.80±0.013% NFE.

In the Lexp-3 group, the meat had a protein content of 22.52±0.50%, lipid content of 1.82±0.044%, ash content of 1.21±0.016%, and NFE content of 0.73±0.011%, resulting in a dry matter content of 26.28±0.73%.

As for the Lexp-4 group, the dry matter content was 26.93±0.71%, of which 23.06±0.49% were proteins, 1.95±0.047% lipids, 1.23±0.015% ash, and 0.69±0.009% NFE.

Statistical analysis of the data showed that for three of the monitored indicators (water content, dry matter content, and protein content), there were statistically significant differences between the Lexp-4 group and the Lc-2 and Lexp-3 groups (Table 6).

ISA Dual chickens (slow-growing) fed diets with different protein levels showed a higher content of dry matter and protein in the pectoral muscle but a lower ether extract content compared to Hubbard JA757 (medium growth) and Ross-308 (fast-growing) [25].

Table 6 Chemical composition of meat in broiler chickens raised in the warm season

Parameters	Batch	Statistical estimators (n=10)		
		$\bar{X} \pm s_{\bar{x}}$	V%	The meaning of the differences
Water (%)	Lc-2	73.78±2.07	8.88	Lc-2 vs Lexp-3: p = 0.8544
	Lexp-3	73.72±2.04	8.74	* Lc-2 vs Lexp-4: p = 0.0237
	Lexp-4	73.07±1.97	8.51	* Lexp-3 vs Lexp-4: p = 0.0331
Dry substance (%)	Lc-2	26.22±0.74	8.90	Lc-2 vs Lexp-3: p = 0.8511
	Lexp-3	26.28±0.73	8.81	* Lc-2 vs Lexp-4: p = 0.0240
	Lexp-4	26.93±0.71	8.36	* Lexp-3 vs Lexp-4: p = 0.0333
Protein (%)	Lc-2	22.44±0.51	7.17	Lc-2 vs Lexp-3: p = 0.8111
	Lexp-3	22.52±0.50	7.05	* Lc-2 vs Lexp-4: p = 0.0289
	Lexp-4	23.06±0.49	6.82	* Lexp-3 vs Lexp-4: p = 0.0375
Fat (%)	Lc-2	1.78±0.044	7.77	Lc-2 vs Lexp-3: p = 0.8438
	Lexp-3	1.82±0.044	7.69	Lc-2 vs Lexp-4: p = 0.7247
	Lexp-4	1.95±0.047	7.58	Lexp-3 vs Lexp-4: p = 0.8154
Ash (%)	Lc-2	1.20±0.016	4.22	Lc-2 vs Lexp-3: p = 0.9317
	Lexp-3	1.21±0.016	4.05	Lc-2 vs Lexp-4: p = 0.9118
	Lexp-4	1.23±0.015	3.88	Lexp-3 vs Lexp-4: p = 0.9106
SEN (%)	Lc-2	0.80±0.013	4.98	Lc-2 vs Lexp-3: p = 0.8797
	Lexp-3	0.73±0.011	4.70	Lc-2 vs Lexp-4: p = 0.8655
	Lexp-4	0.69±0.009	4.31	Lexp-3 vs Lexp-4: p = 0.8754

* significant differences (0,01 < p < 0,05); ** distinctly significant differences (0,001 < p < 0,01); *** very significant differences (p < 0,001).

In a study conducted on three different genotypes (industrial broilers: Ross-308; slow-growing broilers: Hubbard and HB Color) and slaughtered at 63 and 81 days, an increase of 0.90% in meat dry matter, 0.49% in lipids, and 0.32% in proteins was observed in chickens slaughtered at 81 days. Among the tested hybrids, Hubbard achieved the highest increases in dry matter (by 1.06%) and proteins (by 0.44%) and the lowest for lipids (by only 0.46%) [26].

CONCLUSIONS

Following the evaluation of the meat quality obtained from broiler chickens raised at different stocking densities (16-17-19 birds/m²) and in different seasons (winter vs. summer), the following conclusions were drawn:

- In both growing seasons, the pH value was lower in fresh meat and higher in meat refrigerated for 24 hours compared to normal limits, indicating the negative influence of transportation conditions (temperature) on this quality indicator.
- The sensory attributes of the meat were influenced by the stocking density at the time of population, with better appreciation given to chickens that had more space to move during growth. It is worth noting that in the warm season, all sensory attributes received lower scores compared to those given to chickens raised in the cold season.
- Chemically, the meat of chickens raised in the cold season had a higher dry matter content, and consequently higher levels of its components (proteins, lipids, and total minerals), compared to the warm season. This was due to metabolic changes caused by the ability or inability to maintain the microclimate at physiological levels.

In conclusion, using lower stocking densities is a technological procedure that helps maintain meat quality within normal limits, even during extreme periods of the year.

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