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Carcass Characteristics and Meat Quality of Two Populations of Tunisian Local Hens

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Abstract: The aim of this study was to analyze the meat quality of two populations of Tunisian local hens (*Gallus gallus domesticus*). Twenty hens were selected from different farmers: the first phenotype (P1LC) consisted of large hens, while the second (P2SC) included small hens of the same age and same area. Physical analysis, including pH and color, showed no significant differences in pH and color were observed. For P1LC, pH = 5.90 ± 0.124, a*(redness) = 12.76 ± 3.449, b*(yellowness) = 13.31 ± 6.369, and L*(lightness) = 32.71 ± 6.854. For P2SC, pH = 5.98 ± 0.062, a* = 12.45 ± 1.397, b* = 14.09 ± 1.140, and L* = 33.27 ± 0.868. Chemical analysis of water loss during cooking (WL) and water-holding capacity (WHC) revealed that for P1LC, WL = 24.2 ± 1.517% and WHC = 24.2 ± 1.517%, whereas for P2SC, WL = 18.67 ± 0.704% and WHC = 73.67 ± 2.867%. The dry matter content is strongly correlated with the lipid content. Our results revealed a significant difference ($p > 0.05$) in the Dry Matter (DM) for the two populations. Indeed, the results presented in the table showed DM rates equal to 25.467 ± 0.957 % for P1LC and 25.033 ± 1.05 % for P2SC ($p > 0.05$) there is a significant difference. Nutritional analysis showed similar protein and fat content for both phenotypes, with P1LC showing higher dry matter and mineral content. These results provide valuable insights for improving meat quality and promoting sustainable poultry systems for smallholders and rural families.

Keywords: Meat; Nutritional; Phenotypic; Analysis; Local Hens; Populations.

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1 Introduction

Food security is a challenge due to the growing human population and the dwindling availability of nutritional resources. Chicken is one of the most popular meats consumed meats worldwide [1]. Both chicken meat and eggs

are well-known as cost-effective, high-quality protein sources that help support health and nutrition for the expanding population [2,3]. Chicken meat is a versatile, nutritious food, offering a good balance of protein, vitamins, and minerals, while being lower in calories and cholesterol compared to red meat [4–6].

Indigenous chickens, which are well-suited to local environmental conditions and have strong resistance to endemic diseases, play a crucial role in food security and socio-cultural practices in rural communities [7–9]. As a result, even though they tend to be more expensive, the demand for local chicken meat products has risen significantly in countries throughout East Asia and Europe [10].

This trend highlights a growing consumer preference for the quality and sustainability linked to locally raised poultry. A notable variation in choices is seen, particularly among urban populations, where some individuals favor meat from organic, backyard-raised chickens, while others opt for meat from commercial breeds, as these require less time for preparation and cooking. This divergence in consumer preferences could present a challenge to local, backyard-type chicken populations. However, it may also create an opportunity for broader use and recognition of these chickens. [11]. This has been confirmed by the international experience of several countries, where slow-growing native chicken breeds have been able to provide good-quality meat, at a reasonable price, which is the main rationale behind the increasing demand for distinctive products [12]. Products from free-range systems are generally healthier and have had higher welfare standards from a consumer standpoint than those from the conventional intensive system [13]. Indigenous chicken populations still significantly contribute to local economies, especially low-income rural livelihoods, across Asia, Africa, South America, and the South Pacific. As a result, the replacement and hybridization of native breeds with these exotic strains, which may internationally be more commercially competitive, drastically threatens the genetic diversity of worldwide poultry populations [14].

The local chicken populations in Tunisia are an important genetic resource [15], but their carcass characteristics and meat quality have not been extensively studied. With growing interest in promoting local breeds for sustainable production, it is crucial to understand how different populations of Tunisian chickens vary in terms of meat yield and quality. Therefore, the objectives of the current study were to compare carcass characteristics and meat quality across two distinct populations of Tunisian local chickens.

2 Materials and Methods

2.1 Ethical approval

This study was approved by the Ethics Committee of ESAM, Tunisia (Approval No: 04-2021), which outlined several key measures to ensure animal welfare beyond basic housing and feeding. Health monitoring was conducted through regular checks to ensure the well-being of the hens throughout the study. Veterinary care was readily available to address any health issues that arose. Additionally, all personnel involved in the study received training on proper animal handling and welfare practices to ensure humane treatment. These measures were carefully designed to maintain high standards of animal welfare and adhere to ethical research practices throughout the study.

2.2 Animals

Twenty hens of two phenotypes, according to Fehri et al. [15] were randomly selected to analyze the carcass characteristic and meat quality of the meat. The first phenotype (P1LC) which is the large hens and the second phenotype (P2SC) which is the small hens [15] were randomly selected. The experimental trial took place in different farm located in north of Tunisia.

These local hens were given free access to food, which included both dry and fresh feed. Their main diet consisted of wheat and barley grains, available at all times in feeders or scattered around their environment. In addition, wet foods such as mixes of kitchen leftovers or mash were also provided to diversify their diet. Furthermore, they had regular access to fresh plants, such as herbs, vegetables, and roots, which they could peck at. The hens also had the opportunity to forage for and consume earthworms and other small insects, stimulating their natural foraging behavior. This varied and free feeding approach promoted balanced nutrition while encouraging instinctive feeding behaviors.

2.3 Slaughtering and Meat Sampling

Twenty hens from each group were individually weighed before slaughter. Prior to slaughter, the hens underwent a fasting period of 12 hours and were subsequently weighed. The slaughtering process was conducted in a certified slaughterhouse. The animals were slaughtered at the age of seven months in adherence to ethical standards and industry best practices. Post-slaughter, the carcasses were once again weighed. For our analyses, we selected the Brisket portion from each hen.

2.4 Physical Analysis

2.4.1 pH

Immediately after dissection, measurements of pH were performed in line with the modified protocol delineated by deng et al. [16] and consistent with the methodology utilized by Zhou et al. [17]. Briefly, for this procedure, a portable pH meter, previously calibrated with a pH 7 buffer solution, was utilized. The electrode was introduced into the beaker contained a mixture of 5g minced meat sample and 45ml of distilled water when the displayed stable pH value was retained. At each pH determination, the electrode was rinsed with distilled water and wiped dry, to ensure consistency and precision across all readings.

2.4.2 Color

Breast meat color was assessed 24h after the slaughter with a Chroma Meter (model CR-300, Minolta Chromameter CR300, Osaka, Japon). This device records measures of lightness, redness, and yellowness (L*, a* and b*). We ensured that the tip of the Chroma Meter's measuring head was flat against the surface of the breast meat during measurement.

2.5 Analysis of technological

2.5.1 Cooking loos

Cooking loss (CL) was assessed through a designated procedure. Consistent portions of the pectoralis major muscle were chosen, initially weighed, and cooked in a water bath at a maintained temperature of 85°C for duration of 15 minutes. Following this, the samples were individually sealed in airtight bags and immediately immersed in running water to attain room temperature. After drying, the samples were weighed again. The water loss is the difference between the initial and final weights corresponding to the water lost during cooking according to ISO 9920. The Water loss during cooking was determined by the following formula:

$$\text{Cooking loss (\%)} = (\text{Weight before cooking} / \text{Weight after cooking}) \times 100.$$

2.5.2 Water-Holding Capacity

The Water-Holding Capacity (WHC) was determined following a method described by [18]. Initially, a 10 g sample of minced meat was mixed with15 ml of 0.6 M NaCl for 2 minutes, followed by holding in the refrigerator (4° C) for 15 minutes. The mixture is then shaken, centrifuged at 5000 RPM for 15 minutes.
The WHC was determined by the following formula:

$$\text{WHC (\%)} = [(\text{amount of NaCl added} - \text{supernatant volume}) / \text{sample weight}] \times 100.$$

2.6 Chemical Analysis

2.6.1 Dry matter

The principle is to eliminate all the water contained in the samples. Drying was carried out as follows: an empty crucible (w0) was weighed. Then, approximately 3g of the meat sample to be analyzed was placed in the crucible and reweighed again (w1); the crucibles were then put in an oven at 105°C for 24 hours. After 24 hours of drying, the crucible was removed from the oven, it was left to cool for about 10 min in the desiccator, and then it was weighed (w2). The difference in weight corresponds to the loss of moisture and the residue represents the dry matter.
The percentage of dry matter was then calculated using the formula:

$$DM(\%) = \frac{w2 - w0}{w1 - w0} \times 100$$

Where:
W0: weight of the empty crucible
W1: weight of the crucible with the fresh sample
W2: weight of the crucible with the dried sample

2.6.2 Mineral content

The analysis of the mineral content was executed as follows: First, crucibles that had been predried at 105°C for 24 hours were thoroughly cooled in a desiccator and subsequently weighed to ascertain their tare (P1). These crucibles were then placed in a muffle furnace at a temperature of 550°C for duration of 5 hours until the production of white ashes was observed. Following a cooling period in a desiccator, a final weighing (FW) was carried out. The weight of the ashes was determined through the calculation of the weight difference. The mineral content is given by the following formula:

$$MC\ (\%) = [(FW-P1)/TS]\ x100$$

Where:
MC: Mineral content
FW: final weighing
P1: Tare
TS: The test socket (3g)

2.6.3 Total fat content

The determination of Total Fat Content (TFC) was carried out utilizing the Soxhlet extraction method, which is commonly used for the quantification of lipids in dried foods due to its simplicity, accuracy, and official recognition for a wide range of fat content determinations [19]. This method capitalizes on solid-liquid extraction, permitting treatment of solids of varying sizes. In this setup, the Soxhlet apparatus is equipped with a glass flask which houses an adequate amount of pure solvent, in this case, petroleum ether. Additional components include a refrigerant and an extractor. The extractor, which holds a cartridge filled with the solid, is attached to a solvent tank and topped by a condenser. As the system operates, the solvent vaporizes, and then condenses, maintaining contact with the solid throughout.

This systematic procedure allows for an efficient interaction between the solid and the solvent, optimizing the extraction process. The evaporated solvent, upon condensation, retains the capacity to dissolve the substance intended for extraction. The precision of the method ensures high repeatability and consistency in the extraction process.

The procedure started with the weighing of an empty flask (W1). Subsequently, around 3g of the meat sample intended for analysis (S) was placed in a cellulose cartridge and inserted into the Soxhlet apparatus. The flask was then filled with an appropriate volume of solvent (160ml of petroleum ether) and the solution was heated to boiling. The solvent, in its vaporized state, came into contact with the solid and aided in dissolving the substance targeted for extraction.

Once the tank was filled to the level of the elbow, it automatically drained, bringing the solvent and the extracted substance into the flask. After a four-hour hot extraction, the flask was removed from the Soxhlet apparatus and placed in an oven at 105°C for 24 hours for dehydration. Post dehydration, the flask, now containing the extracted fat, was weighed (W2).

The Total Fat Content (TFC) was subsequently computed with the following formula:

$$TFC\ (\%) = [(W2-W1)\ /\ S]\ x\ 100$$

Where:

S: Sample weight in grams.
W1: Weight of the flask before extraction.
W2: Weight of the flask after extraction and drying

2.6.4 Total protein content

The determination of total nitrogen was carried out according to the reference method of Kjeldahl (standard NT 53.13 (1984)). This method consists of attacking the test sample with concentrated sulfuric acid leading to the conversion of organic nitrogen into ammonium ions (mineralization). The mineral nitrogen is then transformed into ammonia by distillation and dosed with Hcl (titration). A blank test was performed for each assay. The nitrogen content (N) expressed as a percentage by weight and is calculated according to the following formula:

$$N\ (\%) = [(V\ Hcl\ x0.0014\ x\ Molarity)/Vessay]\ x100$$

Subsequently, the protein content (% P) can be estimated by multiplying the nitrogen content (% N) by a factor of 6.25 (the generally accepted ratio of protein to nitrogen):

$$\%\ P = \%\ N\ x\ 6.25$$

Where:
V Hcl: Volume in milliliters (ml) of Hcl used for the determination
V essai: Volume in ml of meat used
Molarity: Molarity of HcL 5% = 0.5
N: Nitrogen content
P: protein content
6.25: Transforming coefficient l N in MAT

2.6.5 Myoglobin

The determination of myoglobin was executed as follows: A sample of 5g of finely ground meat were weighed and placed in an identified glass bottle. To this, 1 ml of distilled water and 20 ml of acetone were added successively. The contents were thoroughly mixed to ensure homogeneity, and then 0.5 ml of hydrochloric acid (12N) was added. The vials were tightly closed, agitated, and stowed away in a dark, enclosed area for a 24 hours period. The next day, after filtration, the optical density of the filtrate was carried out using a spectrophotometer at a wavelength of 513 nm. The myoglobin content was calculated as follows:

$$Myoglobin\ (mg/g\ fresh\ muscle) = Optical\ Density \times 8.816.$$

2.7 Statistical Analysis

For the meat analyses, ten samples were collected from each poultry phenotype The laboratory analyzes were duplicated by three repetitions for each analysis. Results are expressed as the mean ± standard deviation of three replicates for all measurements. The repeatability of each mean was tested by analysis of variance (ANOVA). These analyzes were carried out using the XL STAT software in order to compare the different meats and to study the racial effect. The results were processed by the student test. The differences between the means were compared at the 5% threshold.

3 Results

3.1 Live weight and carcass characteristics

The weight and the proportions of the different organs in relation to the two phenotypes were presented in table 1. The average live weight for phenotype 1 at the age of 7 months is 690 g while for P2SC is 1415 g at the same age. And the average carcass weight for the two phenotypes is 372 g and 788 g represent 45% of carcass weight. Liver and gizzard for P1LC is 45g and 50g while for P2SC is 45g and 55g.

Table 1. Live weight and proportions of the different organs compared to the live weight of the two phenotypes.

	Live weight (g)	Carcass weight (g)	Liver (g)	Gizzard (g)
P1LC	$1415^{a} \pm 162$	$788^{a} \pm 0.54$	$45^{a} \pm 0.11$	$55^{a} \pm 0.21$
P2SC	$690^{b} \pm 120$	$372^{b} \pm 0.65$	$45^{a} \pm 0.09$	$50^{b} \pm 0.13$

a, b: Least square of means within a row without a common superscript letter differ ($p<0.05$)

3.2 Meat quality

The analysis of meat quality parameters revealed significant differences between the P1LC and P2SC groups. The pH of the P2SC group reaches a value of 5.98 ± 0.062. The latter presents a slight increase compared to that obtained for the first group which has a pH value of 5.90 ± 0.124. It can be concluded from the ANOVA analysis of variance that there is no significant difference between the pH results of the two groups ($P > 0.05$).

Color is an important component of meat quality because it is a determining factor in the purchasing decision. The consumer considers it as a criterion of product freshness [20]. Meat color is affected by animal age, sex, and the anatomical location of the muscle. In the present study. The muscle taken from P1LC carcasses showed a lightness of ((L* 32.71 ± 6.85) while the P2(SC) of (L* 33.27 ± 0.86). Concerning the redness index (a*) the values were 12.763 ± 3.449 and 12.453 ± 1.397 for P1LC and P2SC, respectively and were not significant as well as the lightness. Finally, the values of the yellowness were b*=13,310 ± 6,369 for the P1LC and 33,277 ± 0,868 for the P2SC showing that there is no significant difference ($p> 0.05$) between the two groups. The kinetics of water loss was higher in P1LC in respect to P2SC 24.2 ± 1.51 % and 18.6 ± 0.70 %, respectively ($p<0.05$).

The water retention capacity measures the ability of the meat to retain the water it contains, during storage and when cooking, see to absorb water in certain transformations. Water retention capacity between the two phenotypes 1 and 2 (88.333 ± 2.160 % and 73.667 ± 2.867%).

Proteins and lipids make up most of the dry matter. Minerals represent a small proportion of the dry matter. The dry content is strongly correlated with the lipid content. Our results revealed a significant difference ($p > 0.05$) in the DM content for the two populations. Indeed, the results presented in the table showed DM rates equal to 25.467 ± 0.957 % for P1LC and 25.033 ± 1.050 % for P2SC. According to ANOVA ($p > 0.05$) there is a significant difference.

The results showed mineral matter rates equal to 1.413 ± 0.102 % for P1LC and 1.223 ± 0.092 % for P2SC. Our results revealed a significant difference ($p > 0.05$) in mineral matter content for both populations. The chemical composition analysis of the local hen's meat highlighted a distinct fat content (3.9 % for P1LC and 0.9 % for P2SC). According to the analysis of variance ($p > 0 .05$) there is a very highly significant difference in fat content for the two populations. Moreover, the meat from both populations exhibited high protein content, with values of 23.100 ± 1.276 % for P1LC and 24.150 ± 1.046% for P2SC. The ANOVA analysis, however, indicated no significant difference in protein content for the meats from the two analyzed breeds.

Interestingly, we found a significant difference ($p < 0.05$) in myoglobin concentration, 1.763 ± 0.513 mg/g meat P1LC and 1.753 ± 0.009 mg/g meat in P2SC.

Table 2. Physico-chemical, nutritional and technological quality of two phenotypes local hens

Meat quality	P1LC (n=10)	P2SC (n=10)	p-value
Meat quality parameters			
Dry Matter (%)	25.46±0.95	25.03±1.05	**
Mineral matter (%)	1.41±0.10	1.22±0.09	*
Protein (%)	23.10±1.27	24.15±1.04	NS
Fat (%)	3.90±0.22	0.90±0.16	****
Myoglobin (mg/g meat)	1.76±0.51	1.75±0.009	**
Water loss at the thigh (%)	24.20±1.51	18.66±0.70	***
Water Holding Capacity (%)	88.33±2.16	73.66±2.86	***
Physical-chemical parameters			
Physical parameters			
a*	12.76±3.44	12.45±1.39	NS
b*	13.31±6.36	14.09±1.14	**

L*	32.71±6.85	33.27±0.86	NS
pH	5.90 ±0.12	5.98±0.06	NS

NS: No significant; (*): P<0,05; (**): P<0,01 ; (***) : P<0,001

4 Discussion

The present research develops an updated evaluation of international research studies focusing on carcass characterization in autochthonous hens breeds worldwide. The imbalance between the economic resources allocated to native genotypes when compared with commercial hybrid strains produces a gap in the knowledge, visualization and impact that such local genotypes will eventually have in the research community and by extension in society.

According to previous studies, the average weights of the liver and gizzard observed in our research were higher to those reported by Eugène et al. [21] who reported an average weight of 24.5 ± 1.96 g for the liver and 36.8 ± 5.57 g for the gizzard in a stray system.

Muscle pH plays a crucial role in meat preservation and stability, as higher pH levels can lead to shorter shelf-life due to increased microbial growth. Our findings did not reveal any significant difference in meat pH among different weight groups, which aligns with the results reported by Hussein [22]. The pH values observed in our study were relatively close to those reported by Li [23] who found pH = 5.9. However, Bianchi et al. [24] reported lower pH in the breast meat of lighter weight broilers than medium and heavy ones. There are values that are similar to those found a pH value 5.86 [25]. According to Elkhazen et al. [26] who observed that the ultimate pH is 5.66. According to Nielsen et al. [27] the rate and the extent of pH decline have a large influence on meat quality characteristics and variation in muscle pH is likely to influence color and the ability of meat to hold water. Higher meat pH is more effective for retaining desirable color and moisture absorption properties [27]. According to Elkhazen et al. [26] the pH value gradually decreases up to the ultimate value, respectively in local poultry (5.66). These results are close with those of El Rammouz et al. [28] who stated that the falling speed of the post mortem pH is significantly influenced by genotype. They found that the pH drop is rapid during the first five hours (5.73). According to the literature, pH post mortem kinetics is characterized by its speed and amplitude.

This difference is explained by the variation in carcass weight which is in disagreement with those found by Elkhazen et al. [26] which has a value of L*=59.74. Results obtained for the parameters redness is in close with those reported by Campo [29]. Moreover, breeding system does not affect meat color parameter (a*) but it affects b*(yellowness). Also, it's close then [20] which has a value of a*= 11.48. For the yellowness index (b*). Similarly, to Bianchi et al. [30] noticed darker breast meat (lower lightness values) in heavy birds when compared with lighter birds

The expulsion of juice from the meat under the effect of the increase in temperature is the major phenomenon that conditions the composition of cooked meats. The indepth study of the factors affecting the losses in juice has shown that they depend mainly on the initial water content of the meat and the kinetics of the temperature inside the meat, itself linked to the size of the meat parts [31]. Which have a value of 22.05 ± 0.62 %. According to the result of Wattanachant et al. [32] who found the myoglobin content is 0.89 ± 0.07.

Our results suggest that P1LC samples generally exhibit higher fat content and WHC, potentially influencing texture and taste, whereas P2SC demonstrates superior moisture retention at the thigh. These differences may result from variations in genetics, feeding practices, or processing methods. This evaluation of key meat quality parameters offers valuable insights for optimizing production and processing to meet consumer preferences and quality standards.

5 Conclusion

In the light of the found results, it was concluded that comparatively with other local poultry breeds in several countries; Tunisian local population presented potentially interesting growth parameters and meat quality characteristics. These results can be a way to improve hens meat quality. Furthermore, these findings can contribute to the development of renewable sources for rural families and smallholders, thereby supporting local economies and enhancing food security.

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