Morphological and phenotypic diversity of indigenous chicken populations in Algeria

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Received: 24/06/2026 ; Accepted: 28/08/2026 s; Published: 01/09/2026

Funding statement:
This research was carried out within the framework of the SCALAMEDI project ("Improving sustainability and quality of Sheep and Chicken production by leveraging the Adaptation potential of LocAl breeds in the MEDIterranean area"), funded by the Partnership for Research and Innovation in the Mediterranean Area (PRIMA), a program supported by the European Union under Horizon 2020, and by the Direction Générale de la Recherche Scientifique et du Développement Technologique (DGRSDT), Algeia.

Abstract
Effective management, conservation, and improvement of animal genetic resources require a comprehensive understanding of their genetic diversity and geographic distribution. The present study aims to describe the diversity of Algerian local chicken populations as the first task of the multi-country Mediterranean project "PRIMA SCALA-MEDI." The second task will aim to develop crossbreeding strategies between two genetically and phenotypically contrasting local chicken populations. From November 2020 to February 2022, 25 linear body measurements and qualitative traits were recorded in 177 adult chickens across 10 locations representing five Algerian agro-ecological zones. Morphological and phenotypic characterization of Algerian local hens revealed substantial variability across studied populations. Key body measurements showed considerable variation, with body length averaging 44.20 ± 9.67 cm and wing length 37.76 ± 6.32 cm, reflecting high morphological plasticity. Plumage was predominantly multicolored (60.5%), with smooth feathering (98.33%) and orange eye color (61.6%) being most common. Sex, breeding system, agro-ecological zone, bioclimatic conditions, altitude, and THI all significantly influenced both morphological and phenotypic traits. Multivariate factorial analyses, including Principal Component Analysis (PCA), Hierarchical Ascending Classification (HAC), and Multiple Correspondence Analysis (MCA), identified three distinct morphological clusters and four phenotypic clusters. The morphological clusters distinguished a scavenging female-dominated group with smaller body dimensions adapted to harsh arid and high-altitude conditions, a transitional mixed group with medium-sized traits linked to moderate mountain climates, and a confined male-dominated group displaying larger morphology associated with selective breeding practices. The four phenotypic clusters further reflected the combined influence of sex, breeding system, regional genetics, and bioclimatic conditions in driving phenotypic diversity across Algerian local hen populations. These findings highlight genetic-environment interactions shaping local chicken adaptations.

Keywords: SCALA MEDI, Genetic biodiversity, Local chicken, Morphometric traits, Phenotypic characterization.

Introduction
Global livestock development now places a high priority on the preservation and sustainable use of animal genetic resources. In response, the Food and Agriculture Organization (FAO) adopted the Global Plan of Action for Animal Genetic Resources in 2007, which created a thorough framework for the identification, assessment, and tracking of livestock biodiversity. The foundation of this strategy plan is phenotypic characterization, as emphasized in FAO recommendations (FAO, 2012; 2013), which provides crucial insights into the diversity and adaptation of regional breeds.

The domestic chicken (*Gallus gallus domesticus*) is the most researched species of bird livestock in the Phasianidae family. Its vast genetic variety and worldwide economic significance make it a perfect model for assessing native chicken populations, especially in African settings. Native chickens are essential to household livelihoods, food security, and agroecological resilience since they are usually well suited to low-input rural production systems (Akouango et al., 2004).

Within the broader African context, Algeria occupies a distinctive yet largely overlooked position in the history of chicken introduction and diversification. Unlike the well-documented eastern introduction route through Egypt (Haller, 1954; MacDonald and Edwards, 1993) or the western African pathways evidenced by archaeological findings in Mali (AD 450–850) and Chad (post-1700 AD) (Mwacharo et al., 2013), the origins and dispersal history of chickens in Algeria remain poorly understood. However, Algeria's strategic location at the crossroads of sub-Saharan Africa, the Mediterranean Basin, and the Middle East suggests that its indigenous chicken populations may have resulted from multiple, independent, or overlapping waves of introduction. These historical processes have likely contributed to the remarkable phenotypic and morphological diversity observed in local chicken populations today.

The poultry industry in Algeria has grown significantly over the past few decades, making a substantial contribution to both rural development and the country's economic output (Kaci, 2015; Ishara-Nshombo et al., 2022). However, interest in traditional poultry systems has increased due to growing customer preferences for natural and locally produced goods as well as growing worries about the ethical and environmental effects of intensive chicken farming (Mlambo et al., 2022; Giller et al., 2021). Despite their adaptive potential, indigenous chicken populations in Algeria remain poorly characterized. Molecular information is scarce, and no comprehensive assessment of their phenotypic diversity is currently available. Although several studies have partially addressed this gap (Mahammi et al., 2014a,b; Berrezoug et al., 2019; Boudali et al., 2020), detailed information on the distribution and morphological variation of these populations across the country's diverse agroecological zones remains limited. This lack of knowledge constrains the development of evidence-based breeding programs and conservation strategies and is further exacerbated by ongoing genetic erosion resulting from uncontrolled crossbreeding, weak population monitoring, and the absence of structured breeding regulations. As emphasized by FAO (2013), integrated phenotypic and molecular characterization of both intra- and inter-population diversity provides the foundation for the identification, conservation, and sustainable use of animal genetic resources. In Algeria, most rural households continue to maintain small flocks of indigenous chickens for egg and meat production outside formal breeding or selection programs, allowing a wide range of morphotypes to persist across contrasting agroecological environments. This diversity represents a potentially valuable reservoir of locally adapted genetic resources that remains largely unexplored. Addressing this knowledge gap requires analytical approaches capable of uncovering the underlying structure of complex morphological datasets, identifying discriminating traits, and classifying individuals and populations, thereby providing a scientific basis for conservation, breeding, and sustainable management of indigenous chicken genetic resources (Mello et al., 2020).

The present study aims to describe the phenotypic and morphological characteristics of indigenous chicken populations across five major agroecological zones of Algeria. Specifically, it seeks to assess morphometric diversity through univariate and multivariate statistical analyses, identify distinct agro-populations, and establish a morphological reference dataset to support subsequent genetic studies. These findings are intended to inform the conservation, improvement, and genetic valorization of Algerian native chicken breeds.

Materials and methods

Ethical statement

This study was conducted within the framework of the PRIMA project SCALA-MEDI (Improving Sustainability and Quality of Sheep and Chicken Productions by Leveraging the Adaptation Potential of Local Breeds in the Mediterranean Area) (https://www.scala-medi.eu/). The research protocol was submitted to and approved by the Ethics and Deontology Committee of the home institution of the corresponding author, in the context of the PhD research project. The study protocol was approved by the Ethical Committee of the University (Reference No. 07, 04 July 2025). All procedures performed during the study complied with institutional ethical standards. The measurements consisted exclusively of non-invasive body morphometric measurements of chickens, carried out in the presence of the animals' owners. Prior verbal consent was obtained from all owners before handling the animals.

Study area

This research was carried out in 18 wilayas that comprise the five agro-ecological zones of Algeria, namely the Littoral zone (LTZ), the Highlands zone (HLZ), Mountain zone (MTZ), Plain zone (PLZ), and Sahara zone (SHZ). (Figure 1). The characteristics of the 5 zones, such as climatic conditions, temperature, humidity index, soil characteristics, and predominant vegetation, are presented in Table 1. The geographic location of the flocks from which the chickens were sampled was recorded using a Garmin GPS (Etrex Vista TM). The altitude of the study sites was obtained from NASA's SRTM (Shuttle Radar Topography Mission) (https://www.earthdata.nasa.gov/). In addition, electronic data on maximum ambient temperature and maximum relative humidity for the past year were obtained electronically from Weather Underground (https://www.wunderground.com/history). These data were instrumental in computing the mean annual Temperature-Humidity Index (THI) using the following formula (NRC 1971):

$$THI = (1.8 \times Max\ T + 32) - (0.55 - 0.0055 \times H) \times (1.8\ Max\ T - 26)$$

Max T: maximum temperature in °C measured by a dry-bulb thermometer; RH: relative humidity in %.

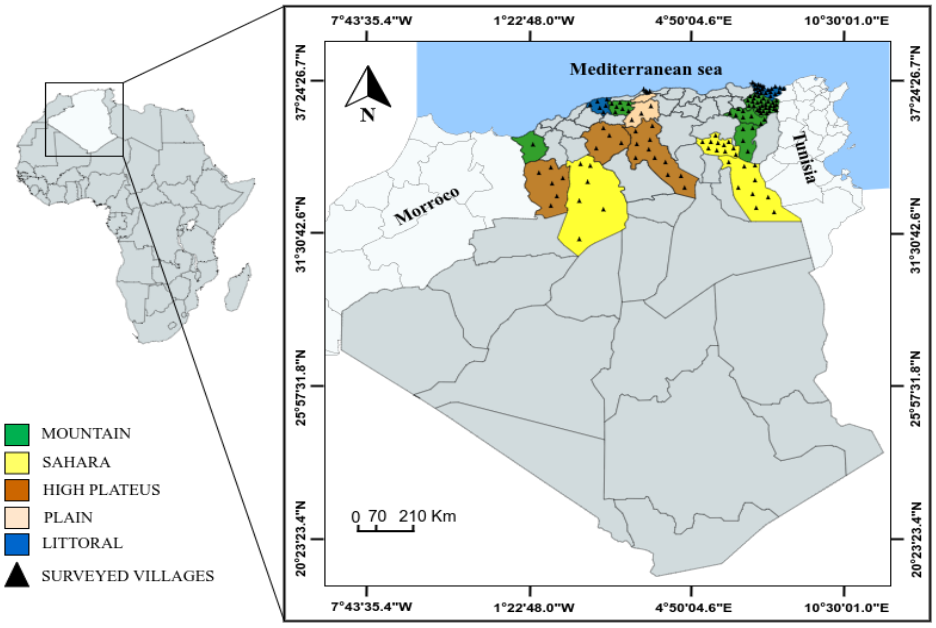


Figure 1. Map of Algeria showing agro-environmental and phytogeographic zones, with the locations of the 32 communes sampled to assess morphological variability in the indigenous chicken population. The map was created using QGIS 3.8 and edited with draw.io

Table 1. Distribution and characteristics of the five agro-environmental zones of Algeria, including the number of indigenous chickens sampled in each zone.

Agroecological zone	Wilayas	Altitude	Climate	Humidity index	Annual rainfall (mm)	Number of samples
LTZ	Annaba	8-35	Humid mediteranean	Hight	800-1000	11
	Taref	9-59	Very humid mediteranean	Very hight	1000-1200	10
	Alger 1	90	mediteranean	Moderate to hight	600-800	3
	Chlef	91-149	arid mediteranean	Low to moderate	400-600	6
HLZ	Tiaret	1135	Semi-arid	Low	300-400	4
	Djelfa	873-1140	Semi-Arid	Low	200-400	11
	Naama	1149	Arid	Very Low	<200	6
MTZ	Souk ahras	27-819	Sub Humid mediteranean	Moderate to hight	600-800	19
	Ain defla	194-383	Semi-arid mediteranean	moderate	400-600	7
	Guelma	207-695	Sub-arid mediteranean	moderate	500-700	11
	Khenchela	1181	Semi-arid mountainous	Low	300-500	4
	Oum Bouaghui	863	Semi Arid	Low	300-500	8
	Tlemcen	622	Sub Humid	Moderate	~19.83	24
PLZ	Medea	682	Mediteranean, Hot summer	Moderate	~25.08	3
	Alger 2	25	Mediteranean	Moderate	600-800	25
SHZ	Beskra	50-118	Arid (Desert)	Low	~125	11
	Oued Souf	72-94	Arid (Desert)	Low	~50	8
	Bayed	1008-1325	Semi Arid	Low	~300	6

LTZ: Littoral zone, HLZ: High plateaus zone, MTZ : Mountain area, PLZ : Plain area, SHZ: Sahara zone

Sampling procedure

Sampling was conducted between November 2022 and April 2023 across five agro-ecological zones in Algeria, following the recommendations of FAO (2013) for the phenotypic characterization of animal genetic resources. A total of 177 birds were sampled. To capture both intra- and inter-population variability across agro-ecological gradients, while remaining consistent with the practical constraints of fieldwork in rural settings, a multistage stratified sampling design was implemented. The five zones were selected to represent contrasting environmental conditions and the diversity of regional chicken ecotypes.

Within these zones, thirty-two communes were selected across seventeen wilayas, with priority given to areas known to harbor established or dense native chicken populations. In each commune, at least four villages were selected at random to ensure broad representation and limit sampling bias. Within these villages, three to five flocks were selected based primarily on farmers' willingness to participate, a strategy commonly recommended for low-input production systems as it facilitates access and encourages community involvement. From each flock, three or more birds were sampled according to farmers' knowledge of lineage, in line with FAO (2013) guidelines, to avoid genetic redundancy and ensure that sampled individuals were unrelated. In addition, 24 to 25 indigenous birds were sampled at the ITELV stations of Tlemcen and Algiers, allowing diversity comparison under traditional free-range or semi-extensive systems and indigenous populations maintained under controlled station management.

The final sample comprised 177 birds, including 61 males and 116 females, distributed across two rearing systems: a confined system (n = 49), and a scavenging system (n = 128), corresponding to the village-based flocks. Across the five agro-ecological zones, sample sizes were as follows: the Mountain zone (MTZ, n = 46), the Highlands zone (HLZ, n = 48), the Littoral zone (LTZ, n = 30), the Sahara zone (SHZ, n = 25), and the Plain zone (PLZ, n = 28). These zones were further classified according to bioclimatic stage into humid (n = 49), semi-arid (n = 83), arid (n = 25), and sub-humid (n = 20) conditions, reflecting the ecological diversity of the sampled populations. Altitude across sampling sites ranged from approximately 0 to 1350 m, while the temperature-humidity index (THI) ranged from approximately 50 to 85, capturing the broad climatic gradient encompassed by the study.

Data collection procedure

Morphological characterization of each local Algerian chicken was performed according to established procedures provided by Dahloum et al. (2016) and the FAO (2013). Phenotypic characterization was performed using a standardized set of quantitative and qualitative descriptors (Table 1). Quantitative assessment included body weight and 18 linear body measurements reflecting overall body size, proportions, and conformation. Qualitative characterization consisted of 10 visually scored morphological traits describing plumage characteristics, body pigmentation, comb morphology, ear lobe features, eye color, shank pigmentation, and skeletal variants, providing a comprehensive description of the external phenotype of each bird. All measures were completed by a single experimented individual to avoid inter-observer bias. Live body weight was recorded using a digital scale (accuracy 0.01 g) and the other linear measures were obtained with a flexible measuring tape and a measuring stick (precision 0.1 cm). These measurements were performed early in the morning before eating to limit fluctuation due to gut fill. The 10 qualitative features were recorded by direct visual observation. In addition, reproductive performance data (egg production and clutch size) were retrieved from owner records and used for additional analysis in a linked study.

Table 2. Description of body measurements and qualitative traits taken on local chicken.

	Body measurements	
.1	**Body Weight (BW)**	Fasting weight taken with a scale in grams
.2	**Body length (BL)**	Distance between the tip of the upper mandible and that of the tail (without feather).
.3	**Back length (BACL)**	Distance measured from the base of the neck (where it joins the back) to the base of the tail, following the contour of the bird's spine.
.4	**Tail length (TL)**	Length from the base of the tail to the tip of the longest tail feather.
.5	**Breast length (BREL)**	Linear distance from the top of the sternum (keel bone) to the end of the keel bone.
.6	**Breast girth (BREG)**	Circumference of the chest measured around the fullest part of the breast.
.7	**Head length (LHEAD)**	Distance from the tip of the beak to the back of the skull.
.8	**Comb width (COW)**	Maximum width of the comb (the fleshy structure on top of the chicken's head).

.9	**Comb height (COH)**	Vertical height of the comb, measured from the base to the highest point.
.10	**Wattle length (WALE)**	Circumference of the chest taken below the wings and at the projecting region of the sternum
.11	**Beak (BRE)**	Defined as the length of the upper edge of the beak;
.12	**Ear lobe length (EARL)**	The length of the ear lobe, which is the fleshy part of the chicken's ear.
.13	**Ear lobe width (EARW)**	Measured at its widest point, perpendicular to its length. The ear lobe is the fleshy, often brightly colored part located below the ear opening of the chicken.
.14	**Neck length (LNECK)**	Distance from the base of the skull to the point where the neck joins the back.
.15	**Wings length (LW)**	Length between the right and the left wings after having gently stretched them at full length.
.16	**Leg length (LLEG)**	Length from the upper joint (hip joint) to the hock joint (the "knee" of the chicken).
.17	**Shank length (SHAL)**	Distance between the articulation of the drumstick and the spur of each shank
.18	**Shank diameter (SHADIA)**	Measured perpendicular in the middle of the shank to the anterior-posterior plane
.19	**Central toe length (CTL)**	Length of the central (middle) toe, measured from the base of the toe to its tip.
Phenotypic physical traits		
.1	**Feather morphology (FM)**	Normal, Silky, Frizzled
.2	**Feather color (FC)**	Red, white, Black, Grey, Yellow,
.3	**Skin color (SKC)**	White, Pink, Yellow, Black
.4	**Shank color (SHC)**	White, Green, Yellow, Black, Blue
.5	**Eye color (EC)**	Red, Orange, Black, Brown
.6	**Ear lobe color (EARLC)**	White, Red, Pink
.7	**Ear lobe shape (EARLSH)**	Oval, Round
.8	**Comb color (CC)**	Red, Pink
.9	**Skeletal variants (SKY)**	Normal, Batam, Multiple spurs,
.10	**Type of comb (TC)**	Single, Walnut, Horn-shape, Pea, Rose,

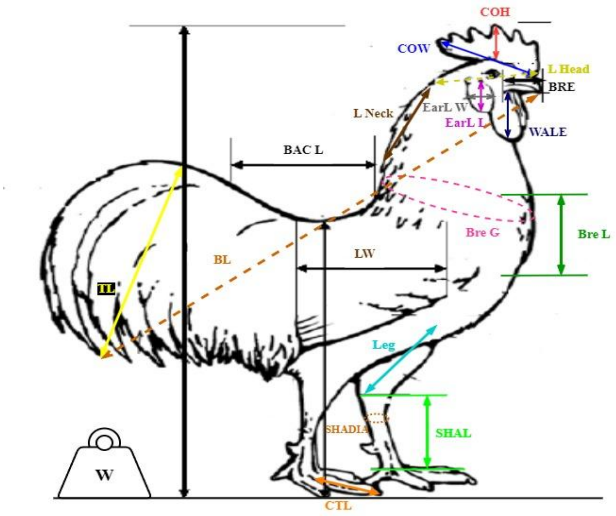


Figure 1. Illustration of the 20 linear body measurements and weight taken on each sampled chicken.
BL: Body Length, B"W": Body Weight, BAC L :Back Length, TL: Tail Length, Bre G: Breast Girth, Bre L: Breast Length, HL: Head Length, COW: Comb Width, COH: Comb Height, WALE: Wattle Length, BRE: BREAK, EARL: Ear Lobe Length, EARW: Ear Lobe Width, LNECK: Neck Length, LW: Wings Length, LLEG: Leg Length, SHAL: Shank Length, SHADIA,: Shank Diameter, CTL: Central Toe Length

Statistical Analysis

Data were originally processed in Excel, then moved to R software (version 4.3.3) for additional statistical analysis. Descriptive statistics were employed to define qualitative physical features and quantitative linear body measures. The normality of data distribution was confirmed with Shapiro-Wilk and Kolmogorov-Smirnov tests. To compare means of body measures for numerous independent factors (sex, breeding system, agroecological zone, climatic circumstances and wilaya of origin), we employed a multivariate ANOVA followed by Tukey post hoc test. Contingency tables and chi-square tests were used to compare frequencies for phenotypic traits. Association of morphological and phenotypic features with altitude and Temperature-Humidity index (THI) level was explored using simple linear regression and logistic regression analysis accordingly.

We used Principal Component Analysis (PCA) on quantitative morphometric measurements to group homogenous entities and minimize data dimensionality, while keeping the major variation patterns. This investigation identified the primary morphologic properties of the chicken populations. Multiple Correspondence Analysis (MCA) was undertaken for the qualitative phenotypic features utilizing five illustrative variables, two qualitative (sex, agroecological zones and wilaya) and two quantitative (altitude and THI). This technique permitted the creation of distinct morphological and phenotypic characteristics in diverse geographies and climatic circumstances, with special emphasis on the impact of heat stress. Data preprocessing was undertaken to increase the performance of the MCA. Specifically, we consolidated the levels with low occurrence, deleted variables with minimal variance (FM, EARLSH, SKV), grouped comparable categories, and standardized the name of the columns to optimize inertia. . Hierarchical Ascending Classification (HAC) was utilized to determine optimal morphologically distinct groupings and establish a comprehensive typology. This method revealed natural clustering patterns based on both quantitative and qualitative traits, with the resulting dendrogram illustrating hierarchical relationships and morphological similarities among chicken populations. The integration of these statistical approaches provided a robust framework for characterizing the genetic biodiversity of local chicken populations in Algeria, yielding valuable insights for conservation strategies and sustainable management of these genetic resources.

Results

Morphological and phenotypic description

Tables 3 and 4 show the descriptive data of the morphological parameters and the phenotypic characteristics of the studied Algerian local hens. The data reveals significant morphological variation within the studied population with the most striking variations observed in BL (44.20 ± 9.67 cm), WL (37.76 ± 6.32 cm), BreG (32.08 ± 5.06 cm), BACL (21.41 ± 3.82 cm), TL (17.10 ± 4.59 cm), and NL (10.24 ± 2.84 cm) suggesting these body measurements are highly variable within the population indicating a substantial morphological plasticity, while the more consistent measurements (like BEAKL 2.65 ± 0.72 cm and EARLW 1.97 ± 0.74 cm) suggest that these traits may be under stronger genetic or developmental control. Some measurements show notably skewed distributions, particularly evident in the CW ranging from 0.1 to 27.2 cm.

The qualitative phenotypic characteristics of the hens revealed significant variation in morphological, integumentary, and plumage characteristics (Table 4 and Figure 3). Based on the color of their plumage, hens were divided into two main groups: multicolored (52.5%) and homogenous (47.5%). Feather color varied by anatomical region in multicolored hens; for example, brown plumage was more prevalent in brown-beige phenotypes (97.98%) but less common in white-grey (21.7%) and multicolored (32.4%) types. Among hens with uniform plumage coloration, black was the predominant colour (32.7%), followed by yellow (27.3%) and white (20.0%), while grey and red occurred less frequently. Smooth (normal) plumage was overwhelmingly predominant (96.0%), whereas frizzled plumage was rare (1.7%). Regular feathering was the most common feather distribution pattern (74.0%), while crested heads, naked necks (4.5%), vulture hocks (2.8%), and feathered shanks (0.6%) were observed at relatively low frequencies. Eye color exhibited noticeable variation, with orange being the predominant phenotype (61.6%). Skin pigmentation was dominated by white or pink (41.8%), whereas yellow (9.6%) and black (6.2%) skin tones were less common.

Similarly, considerable variation was observed in shank, earlobe, and comb characteristics. Green was the predominant shank color (29.9%), although several additional color variants were recorded. Earlobe color was highly variable, with red being the most frequent phenotype (41.2%), while mixed-color earlobes were also common. Round earlobes predominated (57.1%) over oval earlobes. The single comb was the dominant comb type (58.8%), whereas walnut, horn-shaped, rose, pea, and duplex combs occurred at lower frequencies. Red was the predominant comb color (58.2%), followed by pink (27.1%). Skin characteristics showed limited variation, with most hens exhibiting normal skin (83.6%), while bantam and polydactyl phenotypes were observed only rarely.

Table 3. Descriptive analysis of body measurements in the total studied population

Parameters	Units	Mean	SD	Min	Max	Variance
BW	g	1642.17	578.90	800.00	3800	335136.65
BL	cm	44.19	9.67	24	66.5	93.60
BACL	cm	21.41	3.82	11.2	35.00	14.60
TL	cm	17.10	4.58	7.00	39.60	21.05
BreL	cm	17.69	3.70	10.4	33.00	13.70
BreG	cm	32.08	5.06	13.5	59.00	25.61
HL	cm	8.04	2.29	4.20	15.90	5.29
CW	cm	2.67	2.71	0.10	27.20	7.39
CH	cm	3.21	1.64	0.10	7.70	2.71
WL	cm	3.51	1.78	0.30	10.40	3.19
BEAKL	cm	2.65	0.72	0.90	7.82	0.51
EARL	cm	2.30	1.07	0.10	9.80	1.16
EARLW	cm	1.97	0.74	0.63	4.80	0.56
NL	cm	10.24	2.84	5.00	18.30	8.12
WL	cm	37.76	6.32	24.80	72.00	39.96
LLEG	cm	11.45	2.68	4.05	19.00	7.23
SHANKL	cm	7.714	1.69	4.30	14.88	2.86
SANKD	cm	4.56	0.80	2.80	7.50	0.64
CTL	cm	5.23	0.88	2.06	8.30	0.79

BW: Body weight; BL: Body length, BACL:Back length , TL: Tail length, BreL: Breast length, BreG: Breast grith, HL: Head length, CW: Comb width, CH: Comb hight, WL: Wattle lenght , BEAKL: Beak length , EARL: Ear lobe length, EArLW: Ear lobe width, NL: Neck length, WL: Wing length, LLEG: Leg length , SHANKL: Shank length , SHANKD Shank diameter, CTL: Center toe length

Table 4: Frequency and percentage of different modalities of phenotypic variables of local chicken

Parameters	Modalities	F	%
FCT	Homogenous	84	47.5
	Exhibits variation according to the body region	93	52.5
FCH*	Red	4	7.3
	Grey	7	12.7
	White	11	20
	Black	18	32.7

	Yellow	15	27.3
PF	Barred (black/white ; black/red ; red/white)	4	2.3
	Laced (black line on the border of the feather, single or double)	9	5.1
	Spangled (black spots at the feather tip)	53	29.9
	Mottled (white spots at the feather tip or white patches on the body)	22	12.4
FM	Normal	170	96.0
	Silky	4	2.3
	Frizzled	3	1.7
FD	Normal (on the entire body)	131	74.0
	Crested	7	4.0
	Naked neck	8	4.5
	Vulture hocks	5	2.8
	Feathered shank	1	0.6
SC	White	74	41.8
	Black	11	6.2
	Pink	74	41.8
	Yellow	17	9.6
SHC	White	27	15.3
	Green	53	29.9
	Yellow	42	23.7
	Black	13	7.3
	Blue	17	9.6
	Mottled	2	1.1
EC	Red	17	9.6
	Orange	109	61.6
	Brown	35	19.8
	Yellow	3	1.7
	Black	11	6.2
ELC	Red	37	41.2
	White	15	8.5
	Black	2	1.1
	Grey	1	0.6
	Red-white	26	14.7
	Pink-white	32	18.1
	Blue	1	0.6
	Blue-white	2	1.1
ELSH	Oval	51	28.8
	Round	101	57.1
CT	Single	104	58.8
	Wulnut	22	12.4
	Horn shap	13	7.3
	Pea	1	0.6
	Rose	9	5.1
	Duplex CO	2	1.1
CC	Red	103	58.2
	Pink	48	27.1
SKV	Normal	148	83.6
	Bantam	1	0.6
	Polydactyl	1	0.6

*FCT; Feather color type, FCH: Feather color when the body color is homogenous (N=55), PF: Patterning on the feather, FM: Feather morphology, FD: Feather distribution, SC: Skin color, SHC: Shank color, EC: Eye color, ELC: Ear lobe color, ELSH: Ear lobe shape, CT: Comb type, CC: Comb color, SKV: Skeletal variants. * These percentages were calculated among the 55 homogeneous birds*



Figure 3. Representative ecotypes of indigenous chickens from different regions of Algeria.

Factors of variation of local chicken morphology and phenotypes

Morphological variations

Morphological body parameters were compared across sex, breeding system, agroecological zones, bioclimatic conditions, THI, and altitude (Tables 5–8, and Figure 4). Males showed significantly higher values than females in several traits (Table 5), with the most marked differences ($P < 0.001$) in BW, TL, and HL. Moderate differences ($P < 0.05$) were noted in BreL, WL, SHANKL, CH, EARLW, and TL. No significant differences ($P > 0.05$) were found for BL, BACKL, WL, and BreG.

Moreover, morphological features differed substantially amongst breeding systems, demonstrating the effect of management approaches on body development (Table 6). Free-range hens demonstrated higher values in BL, TL, and SHANKD, TL ($P < 0.001$) and HL ($P = 0.000$) indicating the most significant differences. The EARLW was substantially larger in caged chickens ($P < 0.001$). The WL and SANKD also indicated moderate differences ($P < 0.05$), favoring free-range birds. However, no significant changes ($P > 0.05$) were identified in BW or CW, despite a minor trend toward larger weights in confined hens.

Across agro-ecological zones, morphological analysis indicated significant variations in numerous features ($P < 0.001$) (Table 7). Chickens from the PLZ had the longest BL, whereas chickens from SHZ had the greatest BW and BreG. Head and extremities dimensions differed, with SHZ birds displaying the shortest HL and SHANKL, but largest CW. No significant changes ($P > 0.05$) were identified in BreL, EARL, and WL. Moreover, across bioclimatic conditions (Table 8), significant variations ($P < 0.05$) were identified in BW and BL, with Arid area chickens being heavier and Sub-humid region chickens having shorter BL. Humid zones displayed SHANKL and LLEG, whereas Arid zones had lower levels. Head and comb dimensions altered considerably, while other features (e.g., BREG, COH, LW) remained unaffected ($P > 0.05$).

Altitude exhibited a strong detrimental influence on BW and length, although features like BREG and LHEAD were less affected. THI adversely affected weight ($B = -14.49$, $p = 0.005$) and favorably influenced body length ($B = 0.367$, $p < 0.001$). Other characteristics exhibited varying responses, demonstrating substantial trait-environment interactions.

Table 5. Comparison of body weight (in gr) and body measurements (in cm) of Algerian local chicken according to the sex

	Males (N=61)	Females (N=116)	F	Significance level
BW	2082.62±682.31	1410.56±336.15	**39.653**	**xxx**
BL	48.93±10.09	41.70±8.48	**2.143**	**ns**
BACL	23.59±3.71	20.25±3.36	**0.384**	**ns**
TL	19.80±5.48	15.80±3.42	**21.599**	**xxx**
BreL	19.48±4.20	16.75±3.03	**7.561**	**xx**
BreG	33.84±5.78	31.15±4.38	**2.602**	**ns**
HL	8.24±1.54	7.93±2.61	**14.556**	**xxx**
CW	3.59±3.76	2.18±1.79	**3.479**	**ns**
CH	4.529±1.38	2.518±1.32	**0.162**	**x**
WL	5.12±1.69	2.62±1.08	**10.24**	**xx**
BEAKL	2.98±0.85	2.48±0.57	**0.044**	**ns**
EARL	2.92±1.03	1.98±0.96	**2.368**	**ns**

EARLW	2.27±0.88	1.81±0.62	**5.418**	**x**
NL	11.04±3.04	9.81±2.66	**1.096**	**ns**
WL	40.66±6.62	36.24±5.61	**0.025**	**ns**
TL	12.64±2.93	10.82±2.33	**5.732**	**x**
SHANKL	8.47±1.96	7.30±1.38	**7.727**	**xx**
SANKD	4.89±0.75	4.38±0.78	**0.003**	**ns**
CTL	5.53±0.38	5.07±0.88	**0.514**	**ns**

BW: Body weight; BL: Body length, BACL:Back length , TL: Tail length, BreL: Breast length, BreG: Breast grith, HL: Head length, CW: Comb width, CH: Comb hight, WL: Wattle lenght , BEAKL: Beak length , EARL: Ear lobe length, EArLW: Ear lobe width, NL: Neck length, WL: Wing length, LLEG: Leg length , SHANKL: Shank length , SHANKD Shank diameter, CTL: Center toe length

Table 6. Comparison of body weight (in gr) and body measurements (in cm) of Algerian local chicken according to the breeding systems

	Confined System (n=49)	**Scavenging System (n=128)**	**F**	**Significance level**
BW	1695.73	1621.67	**1.76**	**ns**
BL	48.86	42.41	**0.05**	**ns**
BACL	21.96	21.20	**0.003**	**ns**
TL	19.20	16.43	**15.69**	**xxx**
BreL	16.83	18.02	**1.71**	**ns**
BreG	32.39	31.96	**1.08**	**ns**
HL	7.87	8.10	**18.43**	**xxx**
CW	3.22	2.45	**0.00**	**ns**
CH	3.69	3.03	**2.13**	**ns**
WL	4.43	3.14	**4.37**	**x**
BEAKL	3.09	2.48	**0.121**	**ns**
EARL	2.50	2.22	**1.63**	**ns**
EARLW	2.19	1.89	**11.70**	**xx**
NL	10.68	10.07	**1.211**	**ns**
WL	36.40	38.28	**4.22**	**xx**
TL	12.17	11.18	**5.49**	**x**
SHANKL	8.60	7.370	**0.183**	**ns**
SANKD	4.69	4.51	**4.71**	**x**
CTL	5.47	5.14	**0.044**	**ns**

BW: Body weight; BL: Body length, BACL:Back length , TL: Tail length, BreL: Breast length, BreG: Breast grith, HL: Head length, CW: Comb width, CH: Comb hight, WL: Wattle lenght , BEAKL: Beak length , EARL: Ear lobe length, EArLW: Ear lobe width, NL: Neck length, WL: Wing length, LLEG: Leg length , SHANKL: Shank length , SHANKD Shank diameter, CTL: Center toe length

Table 7. Comparison of body weight (g) and body measurements (cm) of Algerian local chicken according to the Agro-ecological zones

	MTZ (N=46)	**HLZ (N=48)**	**LTZ (N=30)**	**SHZ (N=25)**	**PLZ (N=28)**	**F**	**Sig**
BW	1716.21±439.73 a	1460.77±397.30 a	1491.16±510.14 a	2051.88±934.37 b	1627.50±532.10 a	**5.52**	**xxx**
BL	38.86±8.74a	44.07±8.481b.c	42.10±10.46a.b	47.52±6.69c	52.46±8.09d	**12.15**	**xxx**
BACL	20.47±3.90a	20.85±3.73a	22.92±4.22b	21.85±2.42a.b	21.88±4.01a.b	**2.36**	**x**
TL	15.52±3.49a	16.67±4.54a	17.25±3.76a	15.56±3.20a	21.20±5.51b	**8.95**	**xxx**
BreL	17.95±3.55a	17.69±3.54a	18.01±5.08a	17.56±2.36a	17.03±3.60a	**0.33**	**ns**
BreG	31.79±3.97a.b	31.05±4.34a	30.33±5.09a	35.01±2.63c	33.56±7.62b.c	**4.44**	**xxx**
HL	7.88±1.92b	8.85±2.37b	8.58±3.08b	6.349±0.95a	7.82±1.78b	**6.05**	**xxx**
CW	2.61±1.89a.b	1.85±1.73a	1.96±1.85a	4.35±1.00c	3.36±5.19b.c	**4.77**	**xxx**
CH	3.27±1.61a.b	2.67±1.47a	3.37±1.75a.b	3.55±1.46b	3.56±1.88b	**1.96**	**ns**

WL	3.88±2.17b	2.67±1.36a	3.52±2.02a.b	3.80±1.23b	4.08±1.53b	**4.21**	**xxx**
BEAKL	2.63±0.52b	2.28±0.67a	2.54±0.54a.b	2.82±0.28b	3.27±1.03c	**10.72**	**xxx**
EARL	2.47±1.20a	2.23±1.35a	2.24±0.71a	2.49±0.80a	2.05±0.81a	**0.93**	**ns**
EARLW	2.21±0.96c	1.89±0.74a.b	1.80±0.55a.b	2.15±0.54b.c	1.74±0.59a	**2.79**	**x**
NL	10.06±2.95b	10.27±2.85b	10.41±2.74b	8.244±1.98a	12.06±2.33c	**6.79**	**xxx**
WL	36.96±5.23a	37.95±8.78a	39.76±6.88a	37.09±3.17a	37.20±3.81a	**1.07**	**ns**
TL	11.93±2.26b	11.49±3.27b	12.25±2.26b	8.71±1.54a	12.23±1.88b	**9.72**	**xxx**
SHANKL	8.08±1.58b	7.51±1.34b	7.40±1.64b	6.36±0.90a	8.97±1.98c	**10.85**	**xxx**
SANKD	4.82±0.90b	4.39±0.64a	4.39±0.85a	4.80±0.38a.b	4.39±0.96a	**3.06**	**xx**
CTL	5.49±0.87b	4.98±0.99a	5.21±0.92a.b	5.10±0.37a.b	5.37±0.92a.b	**2.24**	**ns**

LTZ: Littoral zone, HLZ: the Highlands zone, MTZ: Mountain zone, PLZ : Plain zone, SHZ : Sahara zone, BW: Body weight; BL: Body length, BACL: Back length , TL: Tail length, BreL: Breast length, BreG: Breast grith, HL: Head length, CW: Comb width, CH: Comb high, WL: Wattle length , BEAKL: Beak length , EARL: Ear lobe length, EArLW: Ear lobe width, NL: Neck length, WL: Wing length, LLEG: Leg length , SHANKL: Shank length , SHANKD Shank diameter, CTL: Center toe length. Values in rows with different letters differ significantly (P≤0.05).

Table 8. Comparison of body weight (g) and measurements (cm) of Algerian local chicken according to bioclimatic conditions

	Humid (N=49)	**Semi-arid (N=83)**	**Arid (N=25)**	**Sub-humid (N=20)**	**F**	**Sig**
BW	1623.53±503.26a	1564.97±455.25a	1949.64±930.61 b	1623.90±569.61a	**2.96**	**0.030**
BL	48.18±11.26b	43.17±8.31b	47.28±6.33a.b	34.81±6.82a	**12.13**	**xxx**
BACL	22.92±3.93b	20.80±3.89a	21.69±2.45a.b	19.91±3.55a	**4.58**	**xx**
TL	19.21±5.33b	15.84±3.36a	16.55±5.57a	17.36±3.55a.b	**5.95**	**xxx**
BreL	16.98±4.14a	17.59±3.51a	17.47±5.57a	20.13±3.95b	**3.697**	**xx**
BreG	31.70±5.76a	31.52±4.07a	34.08±4.22a	32.82±7.18a	**1.903**	**ns**
HL	8.12±2.58b	8.49±2.21b	6.61±1.44a	7.73±2.15b	**4.722**	**xx**
CW	2.15±3.97a	2.48±1.86b	4.19±1.18a	2.81±2.83a	**3.498**	**xx**
CH	3.25±1.73a	3.01±1.60a	3.45±1.57a	3.66±1.67a	**1.095**	**ns**
WL	3.68±1.77a	3.35±1.92a	3.50±1.27a	3.81±1.83a	**0.511**	**ns**
BEAKL	2.88±0.92b	2.49±0.64a	2.76±0.40a.b	2.63±0.60a.b	**3.452**	**xx**
EARL	2.08±0.68a	2.39±1.36a	2.51±0.77a	2.25±0.79a	**1.222**	**ns**
EARLW	1.68±0.53a	2.09±0.84b	2.20±0.73b	1.89±0.61a.b	**4.271**	**xx**
NL	11.66±2.55b	9.87±2.81b	8.11±2.13c	10.91±2.59b.c	**11.152**	**xxx**
WL	38.97±5.79a	36.86±7.48a	36.98±2.92a	39.48±4.62a	**1.797**	**ns**
TL	12.54±2.02c	11.26±3.01b	9.276±1.48a	12.30±2.14b.c	**10.425**	**xxx**
SHANKL	8.66±1.70c	7.53±1.37b	6.48±1.12a	7.735±2.22b	**11.597**	**xxx**
SANKD	4.36±0.82a	4.56±0.75a.b	4.852±0.39b	4.65±1.17a.b	**2.185**	**ns**
CTL	5,38±0,91a	5,21±0,94a	5,02±0,58a	5,22±0,89a	**0,996**	**ns**

BW: Body weight; BL: Body length, BACL :Back length , TL: Tail length, BreL: Breast length, BreG: Breast grith, HL: Head length, CW: Comb width, CH: Comb high, WL: Wattle length, BEAKL: Beak length , EARL: Ear lobe length, EArLW: Ear lobe width, NL: Neck length, WL: Wing length, LLEG: Leg length , SHANKL: Shank length , SHANKD Shank diameter, CTL: Center toe length. Values in rows with different letters differ significantly (P≤0.05).

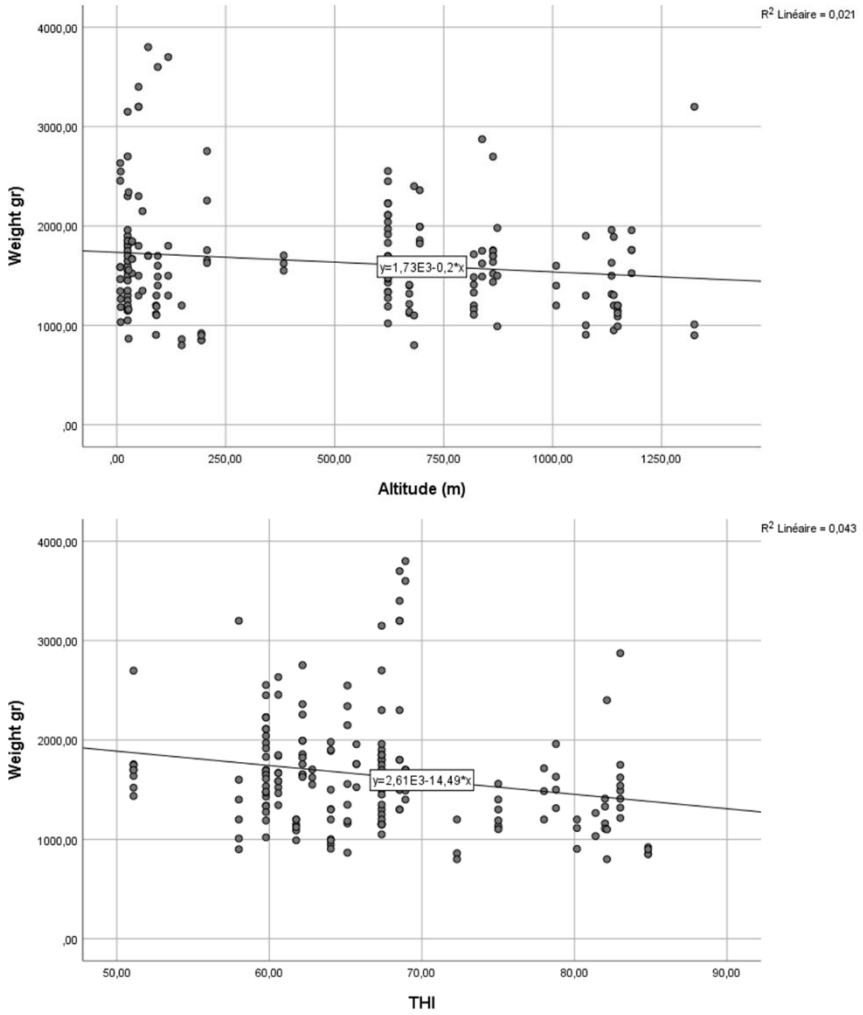


Figure 4: Linear regression result of the relationship of Algerian local chickens body weight (BW, g) with altitude (a) and the annual mean Temperature-Humidity Index (THI) (b)

Phenotypic variations

Phenotypic traits differed considerably across sex, breeding method, agro-ecological zones, bioclimatic conditions, THI, and altitude (Tables 9–12). Sex-based differences were evident (Table 9), with males (40.0%) having greater frequencies of black plumage, and females more typically displaying yellow (27.5%) and multicolored plumage (53%). Tail and neck colors also varied, along with feather morphology; females exhibited more crested heads (4.8%) and bare necks (6.7%), while males had more feathered shanks. Skin pigmentation varied, with yellow skin more prevalent in males (18.0 %) and black skin more frequent in females (8.7%) ($P<0.05$). Eye color was mostly orange in both sexes (74.6% in men and 56.0% in females), with brown significantly more frequent in females (24.1%).

Phenotypic features also vary between breeding systems (Table 10). Scavenging chickens showed more regional feather color diversity (47.5% vs. 5.1% in confined birds), but confined animals had higher frequencies of homogeneous red, grey, white, black, and yellow plumage ($P < 0.05$). Skin color and ear lobe shape differed significantly, with white skin (36.9% vs. 5.1%) and round lobes (60.5% vs. 5.9%) more frequent in scavenging birds. No significant variations were identified for feather patterns, morphology, distribution, shank and eye color, ear lobe and comb features, or skeletal variants ($P > 0.05$).

Plumage coloring exhibited strong regional trends (Table 11). White and colorful birds dominated in chickens from PLZ (100% white among homogeneous plumage types; 92.9% homogenous plumage overall), black was popular in the SHZ (50.0% of homogeneous plumage types), and grey in the LTZ (25.0%). In the mountain zone (MTZ), plumage types were evenly distributed, with yellow plumage being the most prevalent uniform color (52.6%). Bioclimatic regions also altered traits: black plumage prevailed in arid zones (60.0%), grey in humid areas (33.3%, and white/yellow in sub-humid regions (40.0% each). Tail and neck colors varied by zone, as did skin color: yellow was more prevalent in the SHZ (16.0%) and HLZ (12.8%), while white/pink predominated in Mountain (32.6% and 56.5%, respectively) and LTZ (53.3% and 30.0%, respectively). Feather morphology followed regional trends: typical feathering was widespread in the PLZ (100%) and SHZ (100%) zones, crested

heads in MTZ (8.7%), and bare necks in the SHZ (8.0%) and MTZ (8.7%). Feather shanks were scarce, occurring largely in the HLZ and SHZ zones. These patterns represent phenotypic adaptation to local settings.

Bioclimatic variables altered various phenotypic traits of Algerian indigenous hens (Table 12). Homogeneous plumage coloring was more frequent in humid (63.3%) and semi-arid (51.8) locations, whereas birds from arid (80.0%) and sub-humid (75.0%) environments more often displayed feather color variation according to body region ($P < 0.001$). Among homogenous plumage types, black plumage predominated in dry arid regions (60.0%), grey plumage in humid areas (33.3%), and white and yellow plumage in sub-humid regions (40.0% each). Significant variations were also identified for eye color and comb type ($P < 0.01$). Orange eyes were the predominate phenotype throughout all locations, reaching 69.9% in semi-arid areas, whereas yellow eyes were most frequent in dry regions (20.0%). Single combs were the most prevalent comb type (55.0–75.6%), although horn-shaped combs were particularly widespread in dry locations (24.0%). No significant changes were observed for feather morphology, feather distribution, skin color, shank color, ear lobe features, comb color, or skeletal variants ($P > 0.05$).

Table 9. Comparison of the percentage (%) of the qualitative traits in Algerian local chicken according to the sex

		Males	**Females**	**Significance level**
Feather color type	Homogenous	49%	47%	**ns**
	Exhibits variation according to the body region	51%	53%	
Feather color when the body color is homogenous	Red	6.70	7.50	**ns**
	Homogenous grey	0%	17.50	
	White	26.70	17.50	
	Black	40.00	30.00	
	Yellow	26.70	27.50	
Patterning on the feather	Barred	6.90	3.40	**ns**
	Laced	13.80	8.50	
	Spangled	58.60	61.00	
	Mottled	20.70	27.10	
Feather morphology	Normal	95.10	96.60	**ns**
	Silky	3.30	1.70	
	Frizzled	1.60	1.70	
Feather distribution	Normal (on the entire body	89.40	84.80	**ns**
	Crested	4.30	4.80	
	Naked neck	2.10	6.70	
	Vulture hocks	4.30	2.90	
	Feathered shank	00.0	1.0	
Skin color	White	39.30	43.50	**0.xx**
	Black	1.60	8.70	
	Pink	41.00	42.60	
	Yellow	18.00	5.20	
Shank color	White	16.70	17.90	**ns**
	Green	37.50	33.00	
	Yellow	35.40	27.60	
	Black	00.0	12.30	
	Blue	10.40	11.30	
	Mottled	0.00	0.00	
Eye color	Red	11.90	8.60	**x**
	Orange	74.60	56.00	
	Brown	11.30	24.10	
	Yellow	00.0	2.60	

	Black	1.70	8.60	
Ear lobe color	Red	68.10	39.00	**xx**
	White	8.50	10.50	
	Black	0.00	1.90	
	Grey	0.00	1.00	
	Red-white	21.30	15.20	
	Pink-white	0.00	1.90	
	Blue	0.00	0.00	
	Blue-white	0.00	0.00	
Ear lobe shape	Oval	70.20	29.80	**xxx**
	Round	17.10	82.90	
Comb type	Single	80.90	63.50	**xx**
	Wulnut	4.30	19.20	
	Horn shape	0.00	12.50	
	Pea	2.10	00.0	
	Rose	10.60	3.80	
	Duplex CO	0.00	0.00	
Comb color	Red	97.90	54.80	**xxx**
	Pink	2.10	45.20	
Skeletal variants	Normal	100.00	98.00	**ns**
	Bantam	0.00	1.00	
	Polydactyl	0.00	1.00	

FCT; Feather color type, FCH: Feather color when the body color is homogenous, PF: Patterning on the feather, FM: Feather morphology, FD: Feather distribution, SC: Skin color, SHC: Shank color, EC: Eye color, ELC: Ear lobe color, ELSH: Ear lobe shape, CT: Comb type, CC: Comb color, SKV: Skeletal variants

Table 10. Comparison of the percentage (%) of the qualitative traits in in Algerian local chickens according to the breeding system

		Confined system (%)	**Scavenging system (%)**	**Significance level**
Feather color type	Homogenous	22.60	24.90	**xxx**
	Exhibits variation according to the body region	5.10	47.50	
Feather color when the body color is homogenous	Red	0.00	7.30	**x**
	Homogenous grey	0.00	12.70	
	White	1.80	18.20	
	Black	12.70	20.00	
	Yellow	12.70	14.50	
Patterning on the feather	Barred	0.00	4.50	**ns**
	Laced	0.00	10.20	
	Spangled	6.80	53.40	
	Mottled	1.10	23.90	
Feather morphology	Normal	27.70	68.40	**ns**
	Silky	0.00	2.30	
	Frizzled	0.00	1.70	
Feather distribution	Normal	13.20	73.00	**ns**
	Crested	0.70	3.90	
	Naked neck	2.00	3.30	
	Vulture hocks	0.00	3.30	
	Feathered shank	0.00	0.70	
Skin color	White	5.10	36.90	**xxx**
	Black	0.00	6.30	
	Pink	20.50	21.60	

	Yellow	2.30	7.40	
Shank color	White	4.50	13.00	**ns**
	Green	5.20	29.20	
	Yellow	5.20	22.10	
	Black	0.00	8.40	
	Blue	1.30	9.70	
	Mottled	0.60	0.6	
Eye color	Red	1.70	8.00	**ns**
	Orange	19.40	42.90	
	Brown	5.70	14.30	
	Yellow	0.00	1.70	
	Black	0.00	6.80	
Ear lobe color	Red	7.90	40.10	**ns**
	White	0.70	9.20	
	Black	0.00	1.30	
	Grey	0.00	0.70	
	Red-white	2.00	15.10	
	Pink-white	5.30	15.80	
	Blue	0.00	0.70	
	Blue-white	0.00	1.30	
Ear lobe shape	Oval	9.90	23.70	**xx**
	Round	5.90	60.50	
Comb type	Single	13.90	55.00	**ns**
	Wulnut	2.00	12.60	
	Horn shap	0.00	8.60	
	Pea	0.00	0.70	
	Rose	0.00	6.00	
	Duplex CO	0.00	1.30	
Comb color	Red	9.30	58.90	**ns**
	Pink	6.60	25.20	
Skeletal variants	Normal	16.00	82.70	**ns**
	Bantam	0.00	0.70	
	Polydactyl	0.00	0.70	

FCT; Feather color type, FCH: Feather color when the body color is homogenous, PF: Patterning on the feather, FM: Feather morphology, FD: Feather distribution, SC: Skin color, SHC: Shank color, EC: Eye color, ELC: Ear lobe color, ELSH: Ear lobe shape, CT: Comb type, CC: Comb color, SKV: Skeletal variants

Table 11. Comparison of the percentage (%) of the qualitative traits in Algerian local chickens according to agro-ecological zones

		MTZ	**HLZ**	**LTZ**	**SHZ**	**PLZ**	**Significance level**
Feather color type	Homogenous	43.50	54.20	26.70	16.00	92.90	**0.000**
	Exhibits variation according to the body region	56.50	45.80	73.30	84.00	7.10	
Feather color when the body color is homogenous	Red	0.00	13.00	12.50	0.00	0.00	**ns**
	Homogenous grey	0.00	17.40	25.00	25.00	0.00	
	White	10.50	21.70	25.00	25.00	100.00	
	Black	36.80	30.40	25.00	50.00	0.00	
	Yellow	52.60	17.40	12.50	0.00	0.00	
Patterning on the feather	Barred	0.00	9.50	9.50	0.00	0.00	**x**
	Laced	0.00	23.80	14.30	4.80	0.00	
	Spangled	78.30	23.8	61.90	71.40	100.00	

	Mottled	21.70	42.90	14.30	23.80	0.00	
Feather morphology	Normal	97.80	91.70	93.30	100.00	100.00	**ns**
	Silky	0.00	6.20	3.30	0.00	0.00	
	Frizzled	2.20	2.1	3.3	0.00	0.00	
Feather distribution	Normal	82.60	85.40	90.00	92.00	66.70	**ns**
	Crested	8.70	4.20	3.30	0.00	0.00	
	Naked neck	8.70	4.20	0.00	8.00	0.00	
	Vulture hocks	0.00	6.20	3.30	0.00	33.30	
	Feathered shank	0.00	0.00	0.00	0.00	0.00	
Skin color	White	32.60	48.90	53.30	56.00	21.40	**ns**
	Black	41.30	10.60	10.00	4.00	0.00	
	Pink	56.50	27.70	30.00	24.00	71.40	
	Yellow	6.50	12.80	6.70	16.00	7.10	
Shank color	White	17.40	20.80	16.70	12.00	20.00	**ns**
	Green	32.60	27.10	40.00	44.00	40.00	
	Yellow	32.60	22.90	26.70	24.00	40.00	
	Black	4.30	12.50	6.70	12.00	0.00	
	Blue	10.90	14.60	10.00	8.00	0.00	
	Mottled	0.00	0.00	0.00	0.00	0.00	
Eye color	Red	10.90	8.30	20.00	4.00	3.80	**x**
	Orange	67.40	68.80	50.00	48.00	69.20	
	Brown	19.60	12.50	23.30	28.00	23.00	
	Yellow	0.00	2.10	6.70	0.00	0.00	
	Black	0.00	0.00	0.00	0.00	0.00	
Ear lobe color	Red	56.50	39.60	53.30	44.00	33.30	**ns**
	White	6.50	10.40	13.30	12.00	0.00	
	Black	0.00	2.10	0.00	4.00	0.00	
	Grey	2.20	0.00	0.00	0.00	0.00	
	Red-white	8.70	22.90	23.30	8.00	66.70	
	Pink-white	26.10	80.80	6.70	32.00	0.00	
	Blue	0.00	2.10	0.00	0.00	0.00	
	Blue-white	0.00	2.10	3.30	0.00	0.00	
Ear lobe shape	Oval	37.00	33.50	36.70	16.00	33.30	**ns**
	Round	63.00	62.50	63.30	84.00	66.70	
Comb type	Single	69.60	76.60	56.70	68.00	66.70	**ns**
	Wulnut	17.40	8.50	16.70	16.00	33.30	
	Horn shap	4.30	10.60	6.70	16.00	0.00	
	Pea	2.20	0.00	0.00	0.00	0.00	
	Rose	4.30	2.10	20.00	0.00	0.00	
	Duplex CO	0.00	0.00	0.00	0.00	0.00	
Comb color	Red	58.70	75.00	76.70	58.30	100.00	**ns**
	Pink	41.30	25.00	23.30	41.70	0.00	
Skeletal variants	Normal	97.80	97.80	100.00	100.00	100.00	**ns**
	Bantam	0.00	2.20	4.30	0.00	0.00	
	Polydactyl	2.20	0.00	50.50	0.00	0.00	

FCT; Feather color type, FCH: Feather color when the body color is homogenous, PF: Patterning on the feather, FM: Feather morphology, FD: Feather distribution, SC: Skin color, SHC: Shank color, EC: Eye color, ELC: Ear lobe color, ELSH: Ear lobe shape, CT: Comb type, CC: Comb color, SKV: Skeletal variants

Table 12. Comparison of the percentage (%) of qualitative traits in Algerian local chicken according to the bioclimatic condition

		Humid (%)	**Semi-arid (%)**	**Arid (%)**	**Sub-humid (%)**	**Significance level**
	Homogenous	63.30	51.80	20.00	25.00	**xxx**

Feather color type	Exhibits variation according to the body region	36.70	48.20	80.00	75.00	
Feather color when the body color is homogenous	Red	16.70	7.70	0.00	0.00	**ns**
	Homogenous grey	33.30	12.80	0.00	0.00	
	White	16.70	15.40	40.00	40.00	
	Black	16.70	33.30	60.00	20.00	
	Yellow	16.70	30.80	0.00	40.00	
Patterning on the feather	Barred	11.80	5.40	0.00	4.50	**ns**
	Laced	17.60	13.50	5.00	0.00	
	Spangled	52.90	48.60	75.00	78.60	
	Mottled	17.60	32.40	20.00	21.60	
Feather morphology	Normal	95.90	95.20	100.00	95.00	**ns**
	Silky	2.00	3.60	0.00	0.00	
	Frizzled	2.00	1.20	0.00	5.00	
Feather distribution	Normal	91.70	83.10	100.00	75.00	**ns**
	Crested	4.20	4.80	0.00	10.00	
	Naked neck	0.00	8.60	0.00	5.00	
	Vulture hocks	0.00	3.60	0.00	10.00	
	Feathered shank	4.20	0.00	0.00	0.00	
Skin color	White	36.70	40.20	60.00	40.00	**ns**
	Black	6.10	6.10	4.00	10.00	
	Pink	49.00	45.10	16.00	45.00	
	Yellow	8.20	8.50	20.00	5.0	
Shank color	White	15.40	21.70	8.00	15.00	**ns**
	Green	34.60	31.30	44.00	35.00	
	Yellow	34.60	26.50	24.00	25.00	
	Black	7.70	10.80	12.00	15.00	
	Blue	0.00	1.20	4.00	0.00	
	Mottled	0.00	0.00	0.00	0.00	
Eye color	Red	8.50	9.60	0.00	25.00	**xx**
	Orange	63.80	69.90	48.00	45.00	
	Brown	4.30	1.20	0.00	0.00	
	Yellow	0.00	6.00	20.00	5.00	
	Black	0.00	0.00	0.00	0.00	
Ear lobe color	Red	54.20	44.60	44.00	60.00	**ns**
	White	8.30	7.20	16.00	15.00	
	Black	0.00	1.20	4.00	0.00	
	Grey	0.00	1.20	0.00	0.00	
	Red-white	2.50	16.90	8.00	20.00	
	Pink-white	8.30	26.50	28.00	5.00	
	Blue	0.00	1.20	0.00	0.00	
	Blue-white	4.20	1.20	0.00	0.00	
Ear lobe shape	Oval	45.80	41.00	12.00	15.0	**ns**
	Round	54.20	59.00	88.00	85.00	
Comb type	Single	66.70	75.60	60.00	55.00	**xx**
	Wulnut	19.70	14.60	16.00	10.00	
	Horn shap	4.20	4.90	24.00	10.0	
	Pea	0.00	0.00	0.00	5.00	
	Rose	12.50	3.70	0.00	15.00	

	Duplex CO	0.00	1.20	0.00	5.00	
Comb color	Red	75.00	63.90	58.30	90.00	**ns**
	Pink	25.00	36.10	41.10	10.00	
Skeletal variants	Normal	100.00	98.80	100.00	95.00	**ns**
	Bantam	0.00	1.20	0.00	0.00	
	Polydactyl	0.00	0.0	0.00	5.00	

FCT; Feather color type, FCH: Feather color when the body color is homogenous, PF: Patterning on the feather, FM: Feather morphology, FD: Feather distribution, SC: Skin color, SHC: Shank color, EC: Eye color, ELC: Ear lobe color, ELSH: Ear lobe shape, CT: Comb type, CC: Comb color, SKV: Skeletal variants

Morphologic and phenotypic typology

The PCA of morphological traits revealed that the first three factors together explain 42.32% of the total variance (Figure 7), enabling interpretation of relationships among morphological, qualitative, and quantitative variables.

Factor 1: General body size and weight

Factor 1 largely indicates body overall size and weight, with substantial positive loadings for comb height, wing length, breast width, and back length. Positive scores were related with males and chickens kept under confined production systems, representing their substantially larger body size, whereas scavenging chickens tended to have lower scores, indicating smaller body size. Birds from the PLZ had the largest body dimensions, while those from higher-altitude locations, notably the HLZ, were often smaller. Likewise, hens coming from dry locations like Djelfa and Adrar showed lower body size, possibly reflecting environmental limits, whereas birds from the ITELV breeding facilities in Algiers and Tlemcen demonstrated higher body dimensions, consistent with the impacts of selective breeding. Furthermore, altitude was adversely linked with Factor 1 (Figure 6), showing a drop in body size with increasing elevation.

Factor 2: Limb and neck morphology

Factor 2 captures variation in shank length, leg length, comb width, and neck length. Chickens from mountainous regions exhibited higher Factor 2 scores, reflecting relatively longer limbs and necks, which may enhance mobility in rugged terrain. In contrast, chickens from arid regions, particularly the SHZ, tended to have lower scores, indicating shorter limbs and necks, a pattern that may represent adaptation to hot, resource-limited environments by reducing energy expenditure and facilitating thermoregulation.

Factor 3: Body and head proportions

Factor 3 is primarily associated with variation in body length, shank diameter, croup–tail length, and head length. Chickens from Oran and Annaba exhibited higher Factor 3 scores, reflecting relatively elongated body and head dimensions, which may be influenced by local breeding practices. In contrast, birds from Naama, Algiers, and Sétif showed lower scores, indicating a more compact body conformation that may reflect adaptation to local environmental conditions or management systems.

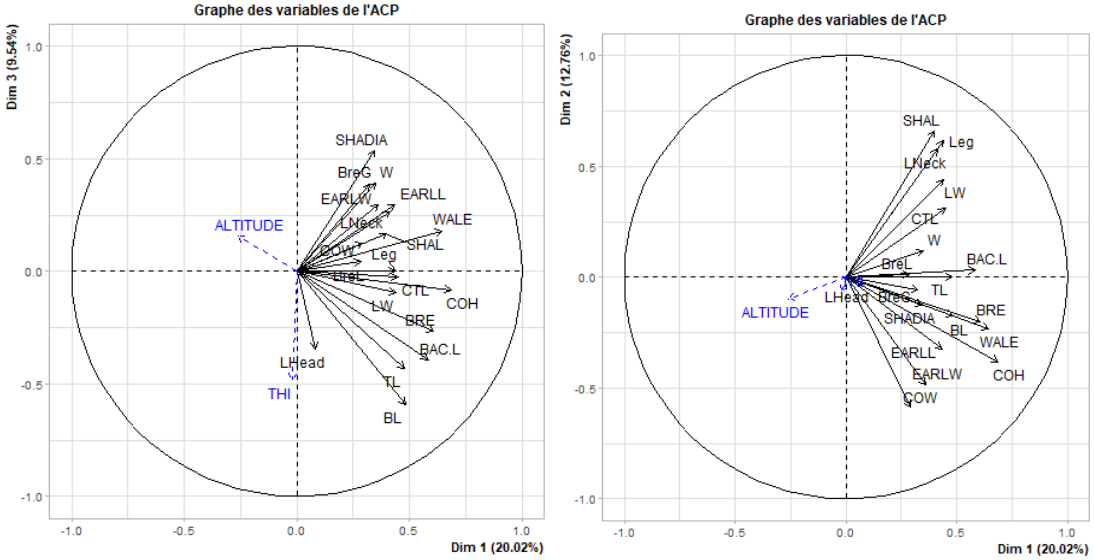


Figure 6: Correlation of morphologic traits and quantitative supplementary variables (altitude and THI) to the first three factors of ACP analysis

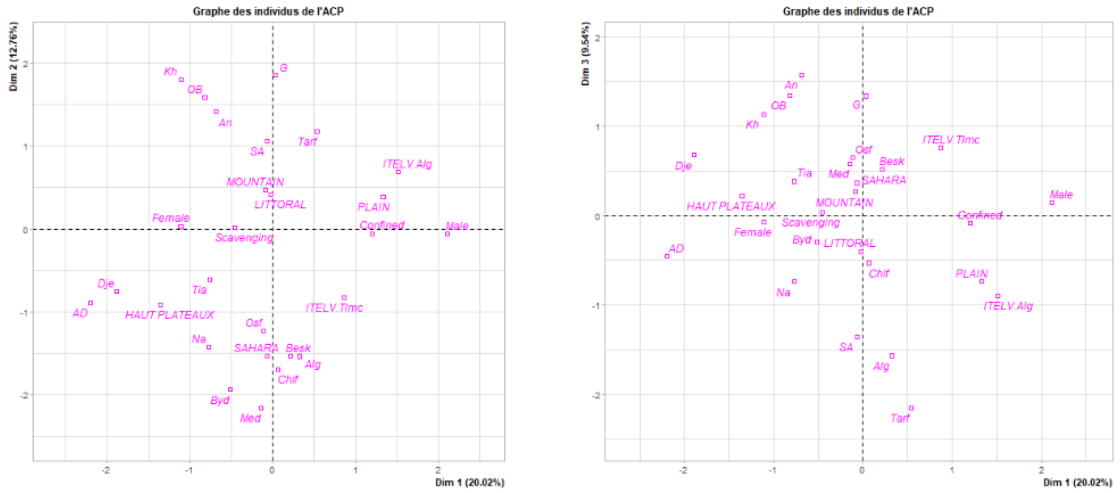


Figure 7: Contribution of the modalities of qualitative supplementary variables (sex, breeding system, bioclimatic region, agro-ecologic conditions and states) to the three first factors of ACP analysis

The HAC analysis for morphological typology of the studied animal according to the two first dimensions of the PCA analysis showed the following clusters (Figure 8):

Cluster 1: Scavenging and female-dominated group
This cluster consists mainly of females (94.6%) and is strongly linked to scavenging systems (89.3%). It is prevalent in HLZ and SHZ (30.4% each) and states like Adrar, Naama, Biskra, and Djelfa, characterized by arid conditions. Chickens in this group have smaller body dimensions: neck (6.2 cm), leg (9.1 cm), and shank length (6.3 cm), all significantly below global means (9.6 cm, 11.5 cm, and 7.7 cm, respectively). Body weight is also lower (1318.7 g vs. 1692.6 g globally). These traits likely reflect adaptation to harsh environments, favoring smaller, lighter birds. The cluster is associated with higher altitudes (619.5 m vs. 469.3 m globally), reinforcing its link to extreme conditions.

Cluster 2: Transitional group with mixed traits
Like Cluster 1, this group is predominantly female (94.6%) but relies less on scavenging (82.1%). It is associated with MTZ (53.6% vs. 41.2% globally) and states like Annaba and Oran, which have moderate climates. Chickens here exhibit medium-sized traits: neck length (11.2 cm) and leg length (12.4 cm) exceed global means (9.6 cm, 11.5 cm). Shank length (8.2 cm) and live weight (39.2 g) are also above average. However, body weight (1318.7 g), breast girth (30.2), and shank diameter (4.2) remain slightly below global means. Weakly linked to altitude (346.7 m), this cluster reflects adaptability to intermediate elevations.

Cluster 3: Confined and male-dominated group with larger morphology
This cluster is male-dominated (84.6%) and strongly associated with confined systems (50.8%), indicating intensive management. It is prevalent in ITELV Tlemcen, Algiers, and Plain regions, where structured breeding is likely. Chickens in this group display larger morphology: body length (49.6 cm), tail length (19.5 cm), and shank diameter (4.9 cm), all above global means (44.2 cm, 17.1 cm, 4.6 cm). Wing area (4.8) and croup-tail length (CTL: 4.45) are also significantly higher. Despite their robust build, these chickens are found at lower altitudes (346.7 m), suggesting adaptation to more favorable environments. Their larger size and compactness likely result from selective breeding and improved nutrition but also a great genetic influence by industrial strands; in the North where the chicken industry is more present compared to the south the breeders have more possibilities to cross their animal with the reformed industrial animals.

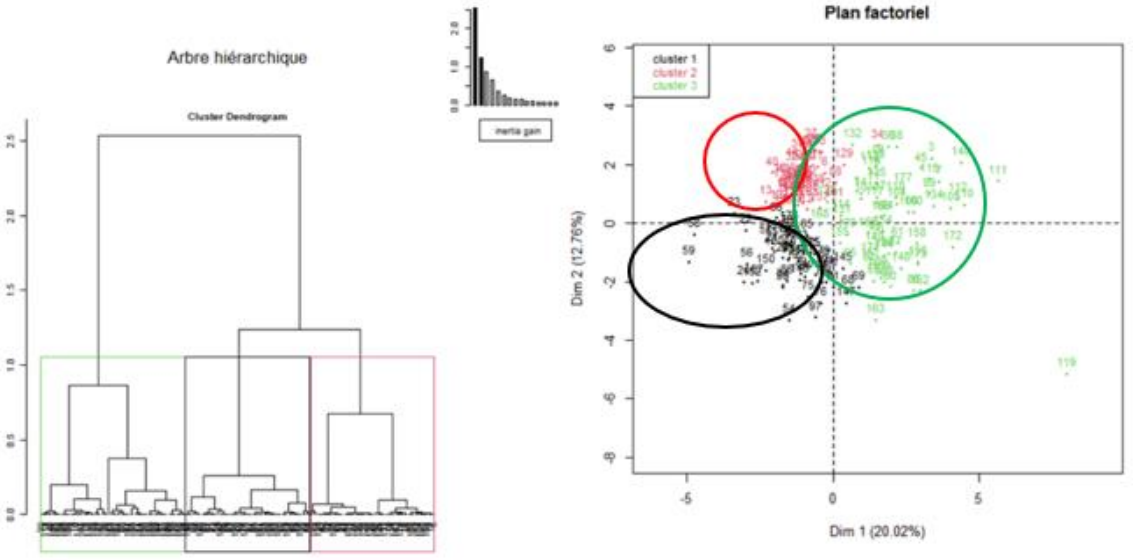
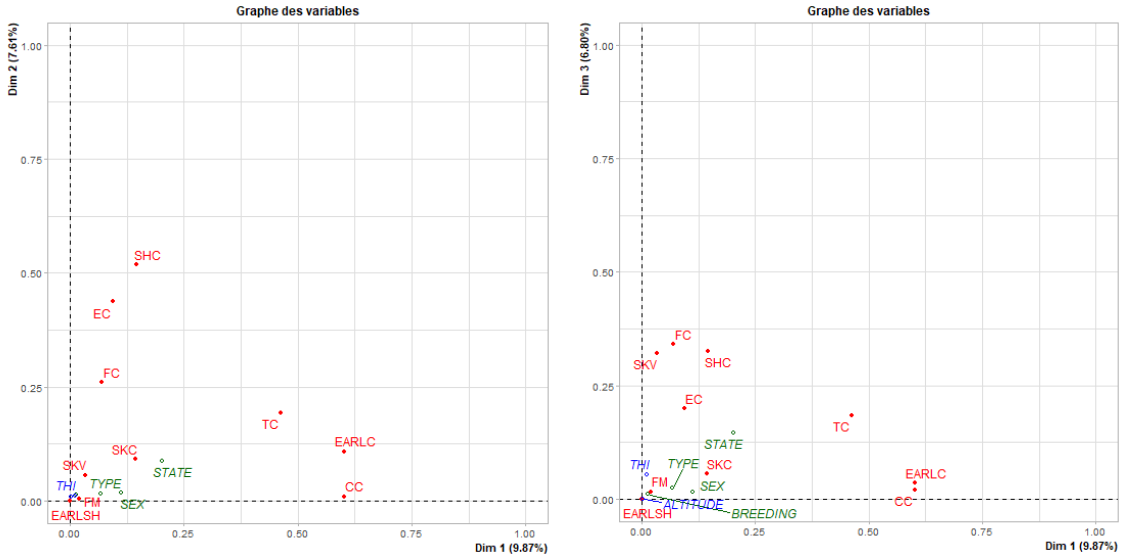
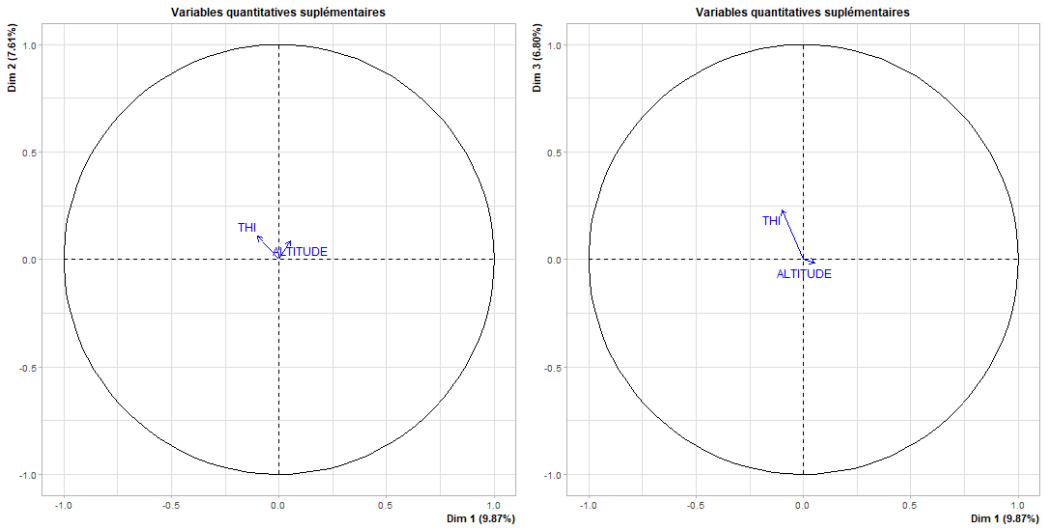


Figure 8: Hierarchical clustering following PCA for morphologic typology of Algerian local chickens

For phenotypic analysis, MCA analysis outputs showed that the first three dimensions of the ACM collectively explain 24.28% of the variance, providing a robust framework for interpreting the relationships among body characteristics and their associations with supplementary qualitative and quantitative variables (Figures 8 and 9).



Figures 9: Contribution of phenotypic active variables and the supplementary qualitative variables (sex, breeding system, bioclimatic region, agro-ecologic conditions and states) to the three first factors of ACM analysis



Figures 10: Correlation of quantitative supplementary variables (altitude and THI) to the first three factors of ACM analysis

Factor 1: Controlled Animals' Phenotypic Traits

This factor highlights traits associated with confined systems and female chickens, such as pink comb color, pink-white ear lobe color, and walnut comb shape. It reflects phenotypic distinctions shaped by controlled management, with strong positive associations for females and confined chickens, and negative associations for males and scavenging birds. This dimension emphasizes morphological traits prevalent under confinement and selective breeding.

Factor 2: Environmental adaptations and free-range traits

Factor 2 captures traits linked to free-range systems and adaptation to arid environments, notably in the Sahara. Key traits include yellow/black shank color and brown eye color. Scavenging chickens and those from arid zones show strong positive associations, while confined chickens show negative associations. This factor represents adaptations to extensive environments, highlighting traits supporting survival in harsh, extensive systems.

Factor 3: Genetic and regional diversity

This factor reflects genetic and regional variation, with key traits including bantam size, white skin, and blue shank color. Chickens from plains and Mediterranean regions align positively, while those from Oran and Ghardaïa show negative associations. Females show slight alignment; males are negatively correlated. Environmental factors like THI play a moderate role, indicating phenotypic traits may also reflect climatic influences. This dimension underscores "Genetic Diversity and Regional Influence.

The HAC analysis for morphological typology of the studied animal according to the two first dimensions of the MCA analysis showed the following clusters:

Cluster 1: Red phenotypes & male dominance

This cluster is strongly associated with red traits, including red ear lobes, combs, and eyes. Males dominate this group, along with yellow skin and pea combs. It is regionally linked to OB and a preference for coastal, low-altitude environments. In contrast, pink phenotypes, white skin, and females are negatively associated. This cluster represents chickens with bright red features and a strong male bias.

Cluster 2: White feathers and adaptation to plains

Chickens in this cluster predominantly have white feathers, black eyes, and white shanks. It is positively associated with females and adaptation to plains and Mediterranean environments. A strong correlation with temperature and humidity conditions suggests resilience to variable climates (Figure 9). Red ear lobes and black feathers are negatively associated. This cluster represents white-dominant chickens with high environmental adaptability and a slight female bias.

Cluster 3: Black and mottled phenotypes with genetic diversity

This cluster is characterized by black feathers, black shanks, and brown eyes. It also includes mottled shank coloration and horn-shaped combs. Environmental influences, particularly temperature and humidity, play a role in shaping these traits. The cluster is linked to warmer climates, where dark phenotypes are more common. Yellow shanks and red eyes are negatively associated. This group represents chickens with diverse genetics and dark-colored traits suited to warm environments.

Cluster 4: Pink and yellow phenotypes with regional adaptation
This cluster includes chickens with pink combs, pink-white ear lobes, and pink shanks, alongside yellow shank coloration and walnut combs. It is positively linked to females and specific regions with unique bioclimatic conditions. Red traits and males are negatively associated. This cluster reflects chickens with pink and yellow phenotypes, regional diversity, and a slight female dominance.

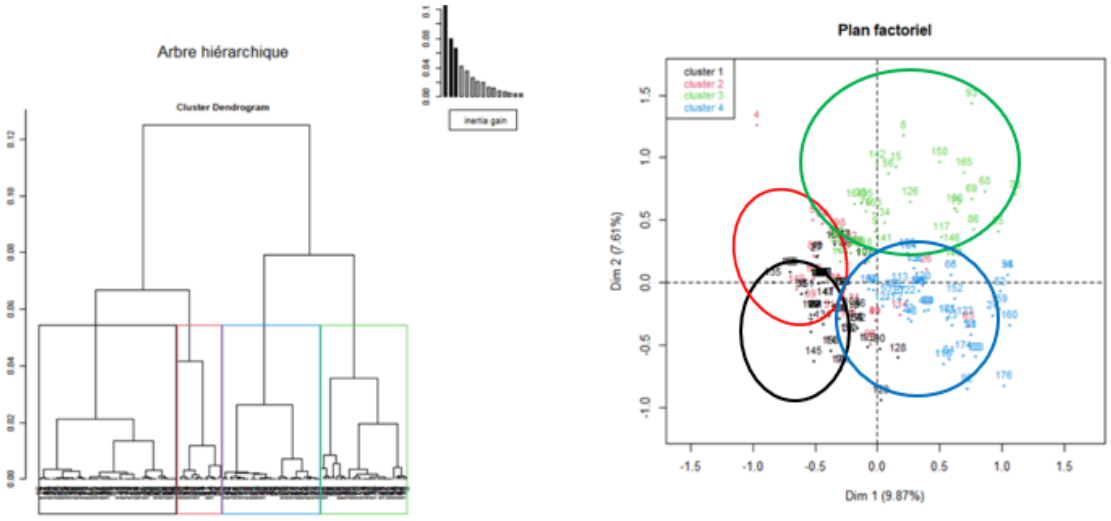


Figure 11: Hierarchical clustering following MCA for phenotypic typology Algerian local chickens

Discussion

The present study was conducted within the framework of the PRIMA SCALA-MEDI project (https://www.scala-medi.eu/), which aimed to investigate the genetic diversity, phenotypic characteristics, and adaptive potential of local sheep and chicken breeds across the Mediterranean region. The work reported here addressed the phenotypic and morphological characterization of indigenous chicken populations, providing essential baseline information for the project's broader objectives. A field survey was carried out on more than 77 farms distributed across five agroecological regions to document farming systems, morphobiometric characteristics, and key zootechnical parameters. In addition, blood samples were collected from 178 birds, comprising 128 females and 50 males, for subsequent molecular analyses, including high-density DNA-chip genotyping and epigenetic profiling.

The results indicated that indigenous Algerian chickens generally exhibited greater body weight than indigenous chicken populations reported in several other African countries. For example, body length, breast circumference, and shank length likewise exceeded values reported for indigenous chickens in Niger (Olawunmi et al., 2008; Ige et al., 2012), Benin (Moula et al., 2012b), Cameroon (Guni et al., 2013), and Côte d'Ivoire (Loukou, 2013). These differences may reflect the genetic background of the studied population, with heterosis resulting from uncontrolled crossbreeding potentially contributing to enhanced growth performance. The substantial variation observed in morphometric traits, particularly body length (BL = 93.603) and wing length (WL = 39.962), further highlighted the considerable phenotypic diversity within the population. Likewise, the wide range of plumage colors was likely attributable to repeated, uncontrolled crossbreeding over several decades, leading to the emergence of diverse color phenotypes (Akouango et al., 2004). Similar patterns of plumage color variation have been reported in indigenous chicken populations from other African countries, where up to 27 plumage color variants have been identified, with black being the most common (approximately 10%). These observations are consistent with the findings of Chabi (2008) in Benin and Moula et al. (2009) in Algeria. The transition from the ancestral golden plumage to black may be linked to a camouflage mechanism developed by chickens to evade predators.

Significant differences in plumage coloration were observed among indigenous hens across the five agroecological zones of Algeria. Such phenotypic diversity has been widely reported in indigenous chicken populations from different geographic regions and is generally considered indicative of substantial genetic variation and population differentiation (Hamadani and Khan, 2016; Xu et al., 2023; Zhi et al., 2023). Similar patterns of plumage variation were previously described in indigenous chickens from western Algeria by Mahammi et al. (2014a). In the present study, white, brown, grey, and multicolored plumage were the predominant color types, with a total of six distinct plumage phenotypes identified. Furthermore, most indigenous hens exhibited normal feather distribution, although several less frequent morphological variants, including frizzled feathers, crested heads, naked necks, and feathered shanks, were also recorded. The crested phenotype was more common in females (23.28%), consistent with previous reports describing its relatively high frequency in local chicken populations (Keambou et

al., 2007). In contrast, the naked-neck phenotype occurred at a low frequency (1.67%), which was lower than the approximately 6% reported in previous studies, suggesting regional variation in the distribution of this trait (Dahloum et al., 2016).

The distribution of tarsus color in the studied population was characterized by white (45.1%), black (31.0%), and yellow (12.1%) tarsi as the predominant phenotypes. These frequencies differed from those reported in neighboring countries. For example, El-Safty (2012) found black to be the predominant tarsus color in Libyan indigenous chickens (39.9%), followed by yellow (24.5%), blue (18.7%), and white (17.9%). Likewise, Dao et al. (2016) reported white (34%), yellow (30%), grey (26.83%), and black (9.17%) as the principal tarsus color phenotypes in indigenous chickens from Togo. The occurrence of yellow tarsi in the Algerian population may be associated with introgression from exotic breeds carrying the W allele, which promotes the deposition of xanthophyll pigments in the skin and tarsal epidermis (Moula et al., 2012c).

The body weight values recorded in the present study, for both sexes, exceeded those previously reported for local Algerian chickens (1.177 kg for males and 0.965 kg for females; Moula et al., 2012 a). This difference may partly reflect the increasing introduction of exotic breeds into local flocks, although this hypothesis would need to be confirmed by further studies specifically addressing crossbreeding pressure in Algerian populations. Similarly, the sexual dimorphism was observed in body weight and morphometric traits, with males consistently showing a larger body dimensions than females, a pattern consistent with previous reports on indigenous chicken populations (Gueye et al., 1998; Msoffe et al., 2002; Bonou, 2006; Keambou et al., 2007). Mean live body weight was 1.25 ± 0.52 kg for males and 1.06 ± 0.29 kg for females. These values were lower than those reported for indigenous chickens in Ethiopia (Getu et al., 2014), the Kabylia region of Algeria (Moula et al., 2012a), and Tanzania (Guni et al., 2013), where mean body weights reached 1.63 ± 0.30, 1.43 ± 0.18, and 2.10 ± 0.29 kg for males, and 1.37 ± 0.20, 1.14 ± 0.18, and 1.53 ± 0.16 kg for females, respectively. Conversely, body weights in the present study were higher than those reported in the Democratic Republic of Congo, where mean values were 1.03 ± 0.72 kg for males and 0.90 ± 0.20 kg for females (Moula et al., 2012 b). Such differences among populations likely reflect variation in genetic background, environmental conditions, urbanization pressures, husbandry practices, and nutritional resources (Abdelqader et al., 2007; Evans et al., 2009; Guisso Taffa 2022).

The multivariate analyses (PCA, ACM, and cluster analysis) revealed marked morphological and phenotypic diversity within the indigenous chicken population and demonstrated that this variability was structured rather than randomly distributed. Body size, body proportions, pigmentation traits, management system, sex, altitude, and geographic origin emerged as the principal factors contributing to population differentiation. These patterns suggest that phenotypic variation results from the combined effects of environmental adaptation, farmer selection practices, and the persistence of heterogeneous genetic resources across contrasting agroecological conditions, consistent with previous findings in indigenous chickens (Gheyas et al., 2021; Chebo et al., 2024; Getachew et al., 2024).

Morphological clustering identified three main groups that differed in body size, production system, and agroecological distribution. The first group consisted of small-bodied chickens predominantly raised under scavenging systems in desert and high-altitude environments. Their reduced body size is consistent with adaptations that improve heat dissipation and lower maintenance requirements under conditions of limited feed availability (King'ori et al., 2010; Melesse, 2014). The predominance of these birds in high-altitude areas also agrees with previous reports describing morphological adaptation of indigenous chickens to low temperatures and reduced oxygen availability (Dana et al., 2010). The second group comprised chickens of intermediate body size, mainly distributed in hilly areas and managed under semi-scavenging systems. These birds exhibited relatively longer necks and legs, characteristics that are likely to improve mobility and foraging efficiency in heterogeneous landscapes (Ajayi, 2010). Their intermediate body development is also compatible with the nutritional limitations commonly associated with semi-scavenging production systems (FAO, 2011). The third group included larger birds maintained under more intensive production systems. Their greater body development is consistent with the combined effects of improved nutrition, better management practices, and, in some cases, selection for growth-related traits (Tadelle et al., 2003; FAO, 2019).

Phenotypic clustering further revealed distinct associations between pigmentation traits, morphological characteristics, and production environments. Red plumage occurred more frequently in male-dominated groups, a pattern that is consistent with the influence of sexual selection and social dominance reported in domestic fowl (Wong and Candolin, 2005). The occurrence of pea combs may also reflect adaptation to colder environments, as previously suggested for indigenous chicken populations (Crawford, 1990). In contrast, white plumage was more common in birds reared under controlled production systems and in warmer environments, where lighter feather coloration may reduce heat absorption through greater solar reflectance (Horst, 1989; Prayaga et al., 2006). Dark plumage and horn-shaped combs were primarily associated with free-range populations from arid regions, supporting earlier observations that these traits may contribute to adaptation under harsh environmental conditions (Yalçın et al., 1997; Goraga et al., 2016). The negative association observed among certain pigmentation traits is likely to reflect the underlying genetic diversity of local populations (Delany, 2003; Liu et al., 2021). Likewise, bantam and light-

coloured birds probably represent genetically differentiated subpopulations maintained through local selection and adaptation (Norris et al., 2007).

Overall, these results illustrated the combined influence of environmental conditions, production systems, and genetic background on the phenotypic diversity of indigenous chicken populations across contrasting agroecological zones (Dana et al., 2010; Yakubu et al., 2013). The relationships observed between morphological traits, phenotypic characteristics, and habitat suggest that both natural and farmer-mediated selection have contributed to local adaptation. The substantial variation detected within the study population highlighted the importance of genetic diversity, environmental heterogeneity, and management practices in shaping phenotypic expression. This diversity represents an important resource for breeding programs, conservation initiatives, and the sustainable management of indigenous chicken populations.

The conservation of this diversity remains essential for maintaining locally adapted genetic resources, particularly in the context of increasing climatic variability (FAO, 2010; Halima, 2007). Comparable findings have been reported in Algerian indigenous chickens, where molecular analyses revealed high levels of genetic diversity and clear differentiation from commercial breeds and wild populations, highlighting the roles of domestication and introgression in shaping current population structure (Mahammi et al., 2015). Future studies integrating genomic analyses with production, adaptation, and fitness-related traits would provide a more comprehensive understanding of the biological mechanisms underlying the phenotypic variation observed in these populations.

Conclusion

The characterization and typology of indigenous Algerian chickens reveal significant morphological and phenotypic variations influenced by genetic diversity, environmental adaptation, and breeding systems. Clustering analysis identified scavenging, small-bodied, female-dominated chickens, adapted to arid and high-altitude environments, transitional chickens with balanced traits for moderate climates, and male-dominated, confined chickens, larger in size due to selective breeding. Phenotypically, color traits were linked to ecological adaptation. The red phenotype was associated with coastal lowlands, while the white-feathered cluster, mostly female, thrived in plains and Mediterranean climates. The black and mottled cluster showed high genetic diversity, suited to warmer regions, and the pink-yellow cluster reflected regional adaptation. These findings highlight the importance of genetic diversity for resilience in diverse agro-climatic zones. Future research integrating molecular genetics and performance evaluations is crucial for the sustainable development of local poultry, preserving their adaptive traits.

Acknowledgments

The authors would like to thank the private farm owners for making the animals available for the study.

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