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Socioeconomic Survey and Physicochemical Parameters of Chicken Eggs concerning the Breeding Systems in Cameroon

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ABSTRACT

Physicochemical characteristics of eggs are still poorly controlled in poultry farming in the city of Ngaoundéré, Cameroon. The present study was thus conducted to characterize the rearing systems in modern poultry farming and to analyze the physicochemical characteristics of eggs from hens reared in deep litter, battery, and backyard systems from August to October 2020 in Ngaoundéré, Cameroon. To this end, 33 farms with approximately 61100 hens (Cobb500 broiler and layer) were surveyed. At the end of this survey, a sample of 180 eggs was collected, with 60 eggs per system for physicochemical analyses. Data included socio-economic and technical characteristics of modern farming systems as well as the physicochemical parameters of the eggs. The obtained results indicated that 90.9% of Cobb500 chicken owners were men. Of the total of the layer's buildings, 73% were equipped with nests. The materials used for feeders were made of wood (54.4%), plastic (21.2%), or cement (6.1%). Moreover, 81.1% of the poultry farmers buy chicken feed on the market while the others prepare their own feed from various ingredients. Preventive and curative prophylactic measures were applied by all livestock farmers, yet 54. 5% were still victims of different diseases. The selling price of a 45-day-old broiler chicken was between 4 and 6 USD, while the price of a 30-egg tray varied between 3 and 4 USD, which contributed to 60-80% of family income for 54.5% of poultry farmers. The high feed cost as well as lack of finance, ingredients, and security were the main issues of poultry farming. Concerning the physicochemical characteristics of eggs, a significant increase in egg weight was noted among backyard (43.50 ± 3.15 g), battery (58.19 ± 4.02 g), and deep litter (63.51 ± 3.91 g) systems. The Haugh's Unit of eggs in the backyard system (72.33 ± 4.42%) was significantly lower than deep litter (82.91 ± 6.76%) and battery systems (86.83 ± 11.42%). The proportions of eggshell and edible contents were similar in all production systems. Yolk lipid (17.63%) and yolk protein (7.11%) in dry matter contents of local breed eggs were higher than those of improved breed from both systems. The findings indicated that modern poultry farming in Ngaoundéré has been poorly developed and backyard eggs were richer in nutrients and consequently highly recommended to use.

Keywords: Breeding Systems, Egg Characteristics, Chicken, Socio-economic survey

INTRODUCTION

Poultry plays an important role in meeting the animal protein needs of people. Poultry meat and eggs are relatively cheap products of good dietary quality, rich in protein and low in fat (Bastianelli and Prin,1999; Sanfo et al., 2012). Because of its many potentialities (a short time in reaching the aim of the production, easier production, low investment requirements, access to all segments of the developing country populations), poultry farming currently possesses a significant position in poverty alleviation strategies of most developing countries (Sonaiya and Swan, 2004). More than 80% of the population, mostly rural in sub-Saharan Africa, is involved in village poultry farming (Fanou, 2006).

The poultry population in Cameroon is about 45 million heads of which 70% are traditional chickens, compared to 24% from improved breeds and 6% from non-conventional species of poultry (Ngandeu and Ngatchou, 2006; Fotsa et al., 2007). Despite this potential, the country is unable to meet the ever-increasing market annual demand for eggs and poultry meat due to population growth.

Indeed, the poultry meat shortage was estimated at 98000 tons in 2015, meaning that an additional 24 million chickens were needed, with an annual increase of 1.2

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million heads per year, to avoid imports and encourage local production. Generally, in the northern part of the country, particularly in Ngaoundéré, modern poultry farming contributes significantly to the consumption of poultry meat. However, its production yield remains low due to the specificities and techniques of production that are not well known. The heavy losses that poultry farmers face originate from the lack of knowledge about environmental factors and breeding techniques. Given its importance, better profitability in this sector must be targeted by identifying the weaknesses in the poultry farming system which can provide solutions for the real development of modern poultry farming in the northern part of Cameroon in general.

Few studies on the characterization of poultry farming systems in the city of Ngaoundéré have mainly concerned village poultry farming (Djitie et al., 2015). Chicks (Cobb500 breed) commonly come from regions located over 500 km away leading to a high rate of mortality during transport. Most of the farmers have a very low level of knowledge about poultry farming, which results in a low level of production. In developed countries, such as the EU countries, egg production follows several international standards. However, in third-world countries in general and Cameroon in particular, poultry farming, packing, and transportation logistics are not structured.

Breeding systems are neither standardized nor controlled which affects the quality and quantity of the resulting products (meat and eggs). Most of the eggs consumed in the town of Ngaoundéré come from regions other than Adamaoua, which are more than 500 km away, causing them to deteriorate during transport.

With this in mind, this study aimed to improve the poultry sector in the northern part of Cameroon in terms of farming management and the quality of the products. To achieve this, a survey on the socio-economic and technical characterization of the modern poultry farming systems has been proceeded followed by a study on the physicochemical characteristics of the eggs from various systems found.

MATERIALS AND METHODS

Ethical approval

Experimental protocols used in the current study were approved by the ethic committee of the Faculty of Sciences, University of Ngaoundere, Cameroon, and strictly conformed with the internationally accepted standard ethical guidelines for laboratory animal use and care as described in the European Community guidelines; EEC Directive 86/609/EEC, of November 24, 1986.

Presentation of the study area

The study was carried out from August to October 2020 in Ngaoundéré which is the capital of the Adamawa Region in Cameroon. Ngaoundéré is a cosmopolitan town located on the Adamawa plateau (7-8°N and 13-14°E) in the Sudano-Guinean ecological zone of Cameroon.

Sampling and data collection

To understand local practices in modern poultry farming in the city of Ngaoundéré, a socio-economic survey on this sector was conducted between August and September 2020 in the three districts of Ngaoundéré, Cameroon. Using a survey questionnaire prepared for this purpose, information was collected from the farmers on the socio-economic characteristics of the farmers, the characteristics and description of the farm, the feeding method and equipment used, disease cases, product sales, constraints, and prospects. The survey covered a total of 33 farms in the three districts of Ngaoundéré (11 in the Ngaoundéré first zone, 7 in the second zone, and 15 in the third zone). In the next step, to investigate the physicochemical characteristics of the eggs, a total of 180 chicken (*Gallus gallus*) eggs were collected and divided into 3 batches (60 eggs from local hens, 60 eggs from the deep litter system, and 60 eggs from the battery system). Eggs from the backyard system were collected at the Dang village market from rural families, while eggs from the deep litter and battery systems were purchased directly from the farms of each farming system. The collected samples were transported to the laboratory of quality control of feed products of the University Institute of Technology, University of Ngaoundéré, in cardboard trays for physicochemical analysis. Once at the laboratory, the eggs were labeled, and then the physical characteristics of 30 eggs from each system were evaluated, while the remaining 30 eggs per batch were used for the evaluation of some physicochemical parameters.

External characteristics of eggs

Weighing and measuring the egg

Eggs were individually weighed on an electronic scale branded Shimadzu UX4200H, Poland, with a capacity of 320 g and 0.01 g accuracy.

Large diameter and height of the eggs were measured using a digital Vernier caliper with a 150 mm range and 0.01 mm accuracy.

Egg Shape Index was obtained by dividing the large diameter by height and multiplying by 100.

$$\text{Shape index} = \left[\frac{\text{Diameter (mm)}}{\text{Height (mm)}}\right] \times 100$$

The specific gravity assessment of eggs was based on Archimedes' principle. Eggs were weighed normally. Displaced water weight (at 22°C) was determined by immersing the eggs in the water of a beaker on the same scale (Zita et al., 2013). The specific gravity of the eggs was then determined using the equation.

$$\text{Specific gravity} = \left[\frac{\text{Normal weight (g)}}{\text{Weight of water displaced (g)}}\right]$$

Egg volume was obtained by placing the egg in a graduated cylinder containing a known volume of water. Egg volume (Ve) was determined by the difference between the volume after the introduction of the egg (Vf) and the initial volume of water (Vi) (Markos et al., 2017).

Ve = Vf-Vi

Internal characteristics of the egg

After 60 eggs of each poultry farming system were broken, the data related to diameter and height of the dense albumen and yolk, yolk color, weight of the albumen, shell and yolk, as well as shell thickness were recorded.

Measuring and weighing albumen, yolk, and shell

Eggs were broken individually and their contents were carefully placed on a 40 cm × 40 cm glass slab on a flat and stable surface. The diameter and then the height of the dense albumen and yolk were measured using the digital Vernier caliper (My Project, Germany). For height measurement, the caliper was attached to tripods to be perpendicular to the glass plate (Radu-Rusu et al., 2014). Yolk color was assessed according to the method of Vuilleumier (1969) which uses a range of yolk colors (Yolk Color Fan® scale, Roche).

After separating albumen from yolk using a 100 ml syringe, yolk was weighed using an electronic balance Model PI-214 (Denver Instruments 214, USA) with a capacity of 210 g and an accuracy of 0.0001 g.

The shells were washed with water to remove the remaining albumen and then dried before being weighed with the same digital scale as previously used (Radu-Rusu et al., 2014). Albumen weight was obtained by calculating the difference between whole egg weight and the weight of the yolk and shell.

Pb = Po-(Pj+Pc)

Where, Pb is albumen egg weight, Pj refers to yolk weight, Po denotes whole egg weight, and Pc signifies shell weight

Using the previously described digital caliper attached to a tripod, the thickness of the shell was taken from shell fragments of the large side, the large diameter, and the small side of the egg (Radu-Rusu et al., 2014).

The different weights and measurements on the internal and external egg characteristics were used to calculate the following parameters:

- Proportion of egg components (%) = $\left[\frac{\text{Shell weight/yolk/white weight (g)}}{\text{Egg weight (g)}}\right] \times 100$
- Percentage of edible matter (%) = proportion of yolk + proportion of albumen
- Egg constituent index (%) = $\left[\frac{\text{Yolk/white height (mm)}}{\text{Yolk/white diameter (mm)}}\right] \times 100$
- Haugh unit (HU) = 100 log $(H+7.57 - 1.7P^{0.37})$

Where, H means albumen height (mm), P signifies egg weight (g), 7.57 is albumen height correction factor, and 1.7 represents the egg weight correction factor (Haugh, 1937).

Albumen and yolk were homogenized separately in large glass Petri dishes. The pH values were obtained by inserting the tip of a pre-calibrated electronic pH meter into each of them. The pH values were noted once the number had stabilized on the display of the pH meter (Bluelab, Germany). The procedure was repeated 5 times for each sample and the average was measured (Radu-Rusu et al., 2014).

Analysis of chemical characteristics

Albumen and yolk were homogenized separately in large glass Petri dishes. The pH values were obtained by inserting the end of a previously calibrated electronic pH meter into each of them. The pH values were recorded once the number stabilized on the pH meter screen.

AOAC (1990) Method No. 925.30 was used to evaluate the dry matter in pre-dried eggs obtained by dehydration in a Memmert SEU 700 forced-air oven at 70ºC.

Crude ash content was evaluated by incineration at 550ºC in a Super Therm C311 incinerator after pre-combustion with a Bunsen tray until the cessation of smoking in accordance with AOAC Specification 900.02 (AOAC, 1990).

Crude protein (CP) was obtained from the evaluation of total nitrogen content by the Kjeldahl method, applied on a Velp Scientifica DK 6 digestion system and UDK 7 distillation system (Italy), according to AOAC Method

No. 925.31. Finally, the total nitrogen content was multiplied by 6.25, which generated the crude protein content. Total lipid content in the form of crude fat was determined by AOAC method No. 925.32 (AOAC, 1990) using a Velp Scientifica Soxhlet SER 148 extractor, Italy.

Statistical analysis of the data

The obtained data were expressed as mean ± standard deviation on the mean. One-way analysis of variance (ANOVA) was used following the general linear model to compare the means of the different parameters. When differences between means were significant, they were statistically separated by Duncan's test at the 5% significance level. The IBM Statistic SPSS (version 25) and Excel 2016 were also used for data analysis and illustration.

RESULTS

Socio-economic and technical survey

Socio-economic status of poultry farmers

Most poultry farmers in the city of Ngaoundéré (90.9%) were men. Of the investigated population, 69.7% of the farmers were Christians, followed by Muslims (30.3%). Regarding the age, 78.8% of the farmers were between 25 and 45 years old, 9.1% were over 55 years old, and only 3% were less than 25 years old. In terms of education, 45.5% of the people surveyed had a university degree, 42.4% could complete secondary education, and only 9.1% had basic education. Poultry farming was the main activity in 84.8% of cases, while traders and civil servants constituted only 9.1% and 6.1%, respectively. Agriculture was the secondary activity for 42.4% of all interviewees. In addition, 75.8% were married and 69.7% had between one and five children. This activity had been carried out for more than 5 years in 39.4% of cases. Poultry production was 100% for profit, 90.9% of farmers had their own sources of financing, and only 9.1% were supported by financing.

Breeding management

Housing

The animals were all sheltered and the buildings were made of long-lasting materials. In 97% of cases, they lived in adapted buildings, and all of them lived in buildings made of brick with sheet metal roofs. These buildings, with sheet metal roofs, varied in size depending on the number of animals they contain. Only 73% of the farmers had a nesting box.

Feeding

All farms were in charge of animal feeding of whom 81.1% supply the required feed from the animal feed store and others (18.2%) made the feed on their own. The equipment used varied from one farmer to another, and the majority (90.9%) had plastic troughs while others (9.1%) used only cement or automatic troughs (Figure 1). Drinking water came from wells (69.7%) and taps (30.3%). Water was provided when the water container was empty in 75.8% of cases. Other farmers provided water twice (6.1%) or three times a day (18.2%). Furthermore, 54.5% of respondents implemented a wooden feeder, 21.2% used a plastic feeder, and only 6.1% utilized an aluminum feeder.

Health management

Mortalities occurred in 30.3% of the farmers each year that affected 1-10% of the chickens. Among these losses, 57.6% were attributed to management problems and 30.3% to disease. Moreover, 84.8% had experienced a disaster and 54.5% attributed it to disease. Based on the description of symptoms (cough, sneeze, weight loss, loss of appetite, diarrhea, and runny nose), the suspected diseases for these losses were New Castle disease, infectious bronchitis, and salmonellosis. All farmers were visited by a veterinary officer. The frequency of the visit was three times a month for 54.5% of the producers, others only asked for a visit in case of necessity (24.2%), once a month for some (15.2%), and finally twice a month for 6.1% of other producers.

Product marketing

For 69.7% of farmers, products are exclusively sold on the farm, compared to 21.1% who sold at the market. The cost of bags of droppings was 4 USD/bag for 75.8% of farmers and 5 USD for 21.2%. According to the respondents, the contribution of poultry farming to their household income was respectively 20 to 40% and 40 to 60% for 18.2%, 60 to 80% for 54.5%, and only 9.1% of the respondents reported that this activity contributed between 80 and 100% to their household income. All farmers agreed that there was no market for poultry alone that operated properly, and all would like to see a market established for the sale of poultry exclusively. Depending on the size, weight, and shape of the animals, the price of a chicken was 5 USD for 84.8% of the farmers (broilers and layers), while the price of chicks varied between 1 and 1.8 USD (broilers and layers) for 51.5% and 23.7% of the respondents respectively.

A: Aluminium feeder **B:** Plastic feeder **C:** Automatic drinker

D: Wooden feeder **E:** Plastic drinker

Figure 1. Some materials used in the modern poultry feeding in the city of Ngaoundéré, Cameroon, from August to October 2020

Problems and prospects

Modern poultry farming is an activity that requires a high level of financial and managerial involvement as well as strict monitoring of animals to obtain optimal results. It should be noted that, however, many problems were encountered and contributed to significant losses. The general distribution of the problems encountered is illustrated in Figure 2. In view of this, for 27.3% of the farmers surveyed, the high cost of feed was the main problem encountered, while 18.2% were victims of problems with the supply of feed and theft. Lack of funding and feed ingredients were the real constraints for 12.1% and 9.4% of the participants, respectively. Only 6.1% and 3% of farmers complained about lack of supervision and marketing problems respectively. Faced with these constraints, 66.7% of the farmers were looking forward to improving the conditions and breeding techniques. Despite the difficulties faced by others, 30.3% wished to increase the size of their livestock, and 3% were looking for outlets.

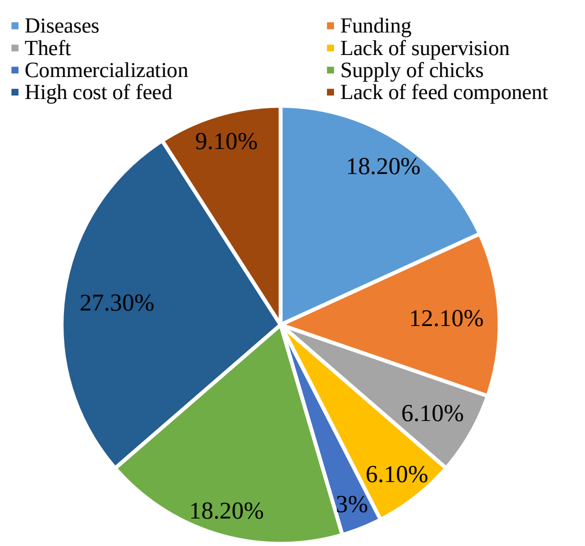

Figure 2. Constraints of modern poultry farming in the city of Ngaoundéré, Cameroon, from August to October 2020

Farmers' demands to the public authorities

The majority of farmers were not a member of a Common Initiative Group or a cooperative (81.8%). In order to improve their activity and obtain satisfactory results, 97% of the breeders requested financial support from the competent authorities and 3% wanted to be supervised.

External characteristics of eggs according to the farming system

Figure 3 illustrates the external characteristics of eggs according to the production system. There was a significant increase ($p < 0.05$) in egg weight among the backyard (43.50 ± 3.15 g), battery (58.19 ± 4.02 g), and deep litter (63.51 ± 3.91 g) systems. The same trend was observed for egg height, with values of 52.51 ± 1.73 mm, 55.35 ± 2.27 mm, and 59.89 ± 2.12 mm for the backyard, battery, and deep litter systems, respectively ($p < 0.05$). Regarding egg diameter, the lowest significant value was recorded for eggs from hens kept in the backyard system (39.59 ± 2.1 mm), compared to eggs from the battery (43.77 ± 0.9 mm) and deep litter (43.86 ± 1.19 mm) systems, which otherwise were not significantly different ($p \geq 0.05$). The same observations were made ($p \geq 0.05$) with density where the values obtained were 1.05 ± 0.06; 1.09 ± 0.06 and 1.10 ± 0.08 respectively for the battery, backyard, and deep litter systems. Both egg volume and weight were significantly affected by the rearing systems. The lowest ($p < 0.05$) value was recorded for eggs from the backyard system (41.75 ± 3.89 ml), followed by battery (53.80 ± 4.01 ml) and finally deep litter (58.05 ± 5.52 ml). The shape index of eggs was significantly ($p < 0.05$) higher with the battery system (79.16 ± 2.46%) compared to the backyard (75.45 ± 4.45%) and deep litter (75.86 ± 3.12%) systems where any significant difference ($p < 0.05$) was noticed.

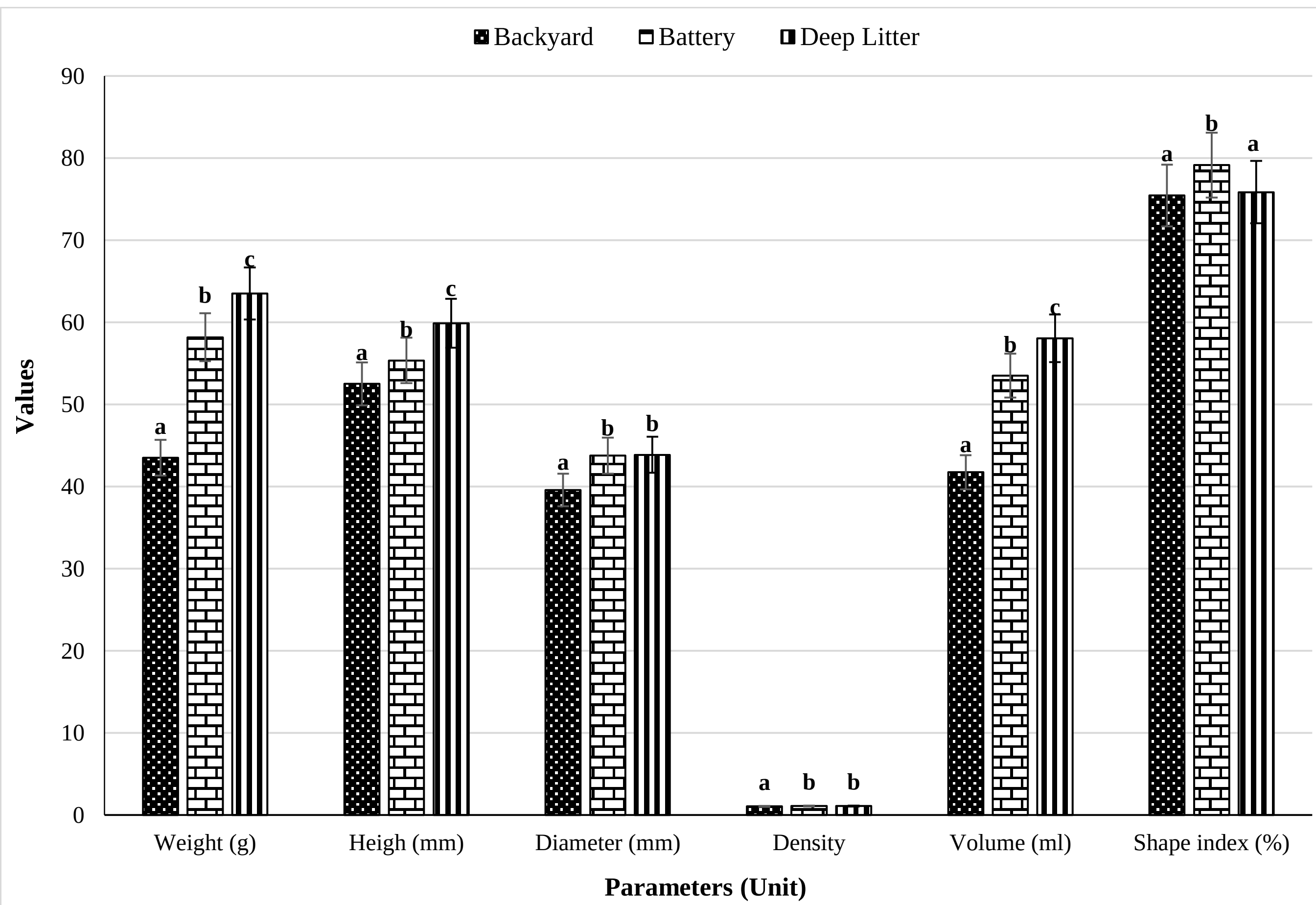

Figure 3. External characteristics of layer hen eggs according to production systems in the city of Ngaoundéré, Cameroon, from August to October 2020. [a,b,c]: Values with the same letter are not significantly different per parameter ($p > 0.05$)

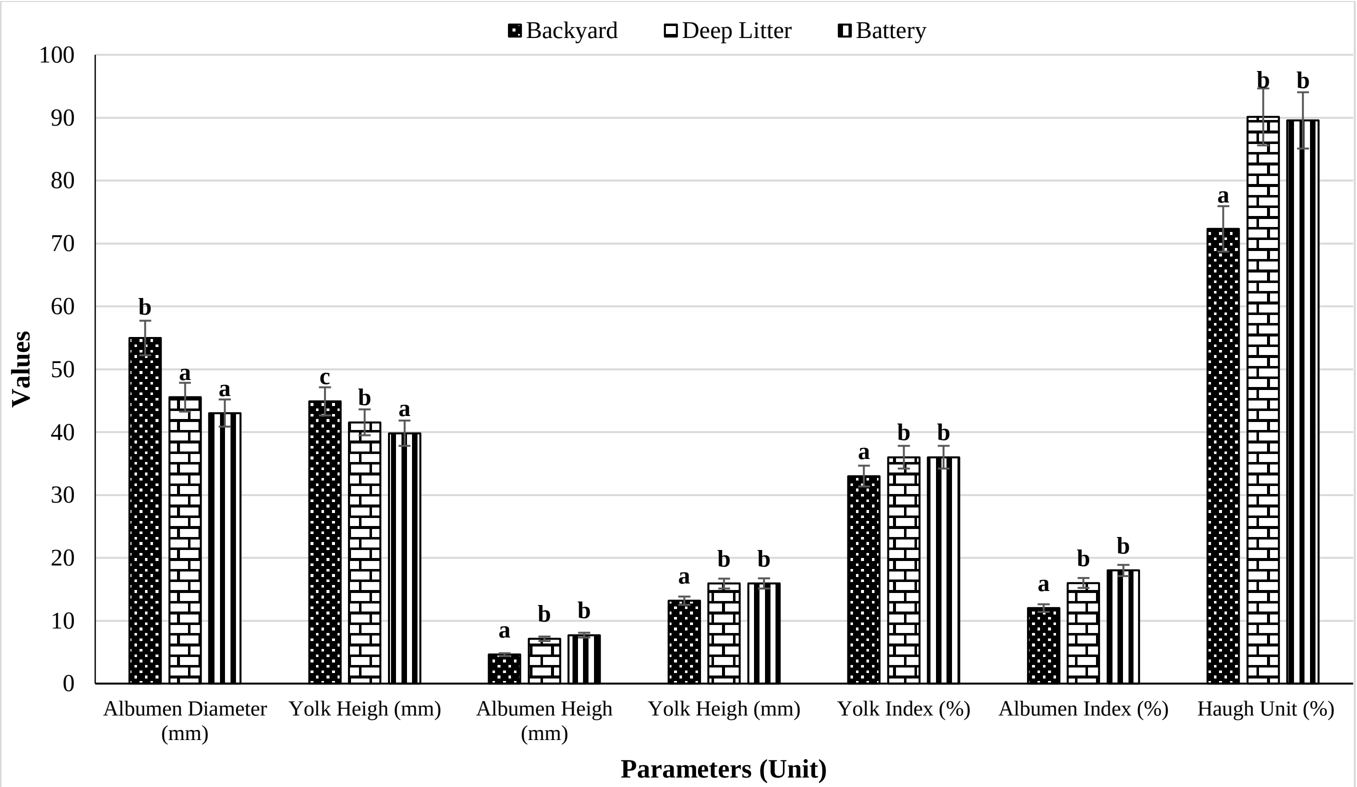

Figure 4. Internal characteristics of layer hen eggs according to production systems in the city of Ngaoundéré, Cameroon from August to October 2020. [a,b,c]: Values with the same letter are not significantly different per parameter ($p > 0.05$)

Egg internal characteristics

Measurements, yolk index, egg albumen index, and Haugh unit according to the production system

The evolution of the internal characteristics of the eggs according to the production system is shown in Figure 4. Albumen and yolk diameters were significantly ($p < 0.05$) higher in eggs from backyard hens (54.99 ± 18.31 mm and 44.91 ± 1.95 mm, respectively), compared to the other systems. The values obtained for albumen diameter were similar for the deep litter and battery systems, while the yolk diameter of eggs from the deep litter system (41.56 ± 1.74 mm) was significantly ($p < 0.05$) higher than that of the battery system (39.83 ± 1.72 mm). Regarding the yolk and albumen height parameters, the significantly lower values were recorded for eggs from hens reared in the backyard system (13.18 ± 1.18 mm and 4.61 ± 0.51 mm), compared to the deep litter and battery systems, which were otherwise comparable ($p < 0.05$). Similar observations were made for yolk and albumen indexes as well as the Haugh Unit. Eggs from the backyard system exhibited values of 12 ± 0.01%, 33 ± 0.03%, and 72.33 ± 4.42%, respectively, for albumen index, yolk index, and Haugh Unit which were significantly lower ($p < 0.05$), compared to the battery and deep litter systems.

Weight and proportions of yolk and albumen according to the production system

Table 1 shows the variation in weight of egg constituents, yolk, and albumen proportions according to the production system. It can be seen that the highest yolk weight (15.43 ± 1.3 g) was recorded in the deep litter system eggs and was similar to that of the backyard system. However, the albumen weight (41.83 ± 3.08 g) of the deep litter system was significantly ($p < 0.05$) higher than the other two systems. Regarding the shell weight, there was no significant difference between the eggs from the deep litter system and the battery system, but it was higher than that from the backyard system. As indicated, the proportions of albumen and yolk of eggs from the deep litter system were similar to those of the backyard system.

Shell characteristics according to production systems

Shell characteristics according to production systems are presented in Table 2. The production system showed no significant effect in shell proportions. The highest value of shell thickness at the large side of eggs was recorded for eggs from the battery system (0.60 ± 0.16 mm), which was significantly higher than those recorded for eggs from the deep litter and backyard systems ($p < 0.05$). Same patterns were found for the shell thickness at the medium and small ends. Moreover, the highest average shell thickness was recorded for eggs from the battery system (0.56 ± 0.08mm), compared to eggs from the deep litter and battery systems.

Egg chemical characteristics according to production systems.

Yolk and albumen pH

Table 3 presents the variations in yolk and egg albumen pH according to production systems. The highest yolk pH value was recorded for eggs from the backyard system (6.96 ± 0.1), which was similar to the battery system (6.81 ± 0.1) pH, but higher than that of the eggs from the deep litter system. With regard to albumen pH, there was no significant difference among the three groups regardless of the production system considered ($p \geq 0.05$). In all investigated systems, the albumen pH was higher than that of the yolk.

Dry matter, protein, and lipid content

In Figure 5, the chemical characteristics of the eggs are presented in relation to the different production systems. It appeared that the dry matter of the albumen was similar ($p \geq 0.05$) regardless of the production system. The highest dry matter content was recorded in battery eggs (14.64 ± 1.01%), followed by eggs from the deep litter (13.92 ± 1.02%), and backyard systems (13.56 ± 0.94%). The yolk dry matter represented almost half of the fresh sample. No significant differences were found in the values recorded in the three systems. However, the highest yolk dry matter content was obtained in eggs from the deep litter system (44.36 ± 3.26%) followed by the battery (42.02 ± 1.33%) and backyard (35.34 ± 12.6%) systems (Figure 5A).

The determination of soluble protein in egg albumen and yolk showed that egg yolk contained less protein than egg albumen. The protein content in egg albumen of the deep litter (5.11 ± 0.45%) differed significantly from that of the other two groups ($p < 0.05$). Battery (7.07 ± 0.48%) and backyard (7.11 ± 0.15) systems had comparable ($p \geq 0.05$) values of protein content. The same trend was observed for the protein content of the yolk in the deep litter, backyard, and battery systems as 8.87 ± 0.48%, 9.34 ± 0.6%, and 9.52 ± 0.29%, respectively (Figure 5B).

The lipid content of the yolk as a percentage of dry matter varied according to the farming systems. The significantly ($p < 0.05$) highest value of yolk lipid content (Figure 5D) were recorded in backyard system eggs (41.97 ± 1.2%), compared to deep litter (34.57 ± 0.6%) and battery (33.38 ± 0.9%) systems, which also presented similar ($p \geq 0.5$) values (Figure 5C). The same observations were made with regard to protein content as a percentage of fresh matter.

Table 1. Weight and proportions of layer hen egg constituents according to farming systems between August and October 2020 in the city of Ngaoundéré, Cameroon

Farming systems \ Parameters	Yolk weight (g)	Albumen weight (g)	Shell weight (%)	Yolk proportion (%)	Albumen proportion (%)
Backyard	15.20 ± 1.07^b	23.88 ± 2.87^a	4.43 ± 0.70^a	35.10 ± 3.3^b	54.75 ± 3.31^a
Battery	14.23 ± 0.90^a	37.92 ± 3.87^b	6.03 ± 0.4^b	24.53 ± 1.83^a	65.06 ± 2.36^b
Deep Litter	15.43 ± 1.3^b	41.83 ± 3.08^c	6.25 ± 0.5^b	24.31 ± 1.67^a	65.84 ± 1.7^b

^{a,b,c}: Values with the same letter are not significantly different per parameter ($p > 0.05$)

Table 2. Shell characteristics of layer hen according to farming systems between August and October 2020 in the city of Ngaoundéré, Cameroon

Parameters \ Farming systems	Backyard	Battery	Deep Litter
Proportion (%)	10.15 ± 1.27^a	10.42 ± 1.05^a	9.85 ± 0.73^a
Large side thickness (mm)	0.33 ± 0.03^a	0.60 ± 0.16^c	0.43 ± 0.03^b
Medium side thickness (mm)	0.33 ± 0.04^a	0.51 ± 0.09^c	0.44 ± 0.03^b
Small side thickness (mm)	0.37 ± 0.06^a	0.57 ± 0.17^c	0.43 ± 0.05^b
Average thickness (mm)	0.35 ± 0.03^a	0.56 ± 0.08^c	0.44 ± 0.03^b

^{a,b,c}: Values with the same letter are not significantly different per parameter ($p > 0.05$)

Table 3. pH variations of yolk and albumen according to farming systems between August and October 2020 in the city of Ngaoundéré, Cameroon

Parameters \ Farming systems	Backyard	Battery	Deep Litter
Yolk pH	6.96 ± 0.10[b]	6.81 ± 0.10[ab]	6.63 ± 0.19[a]
Albumen pH	9.42 ± 0.06[a]	9.40 ± 0.06[a]	9.36 ± 0.16[a]

[a,b,c]: Values with the same letter are not significantly different per parameter (p > 0.05)

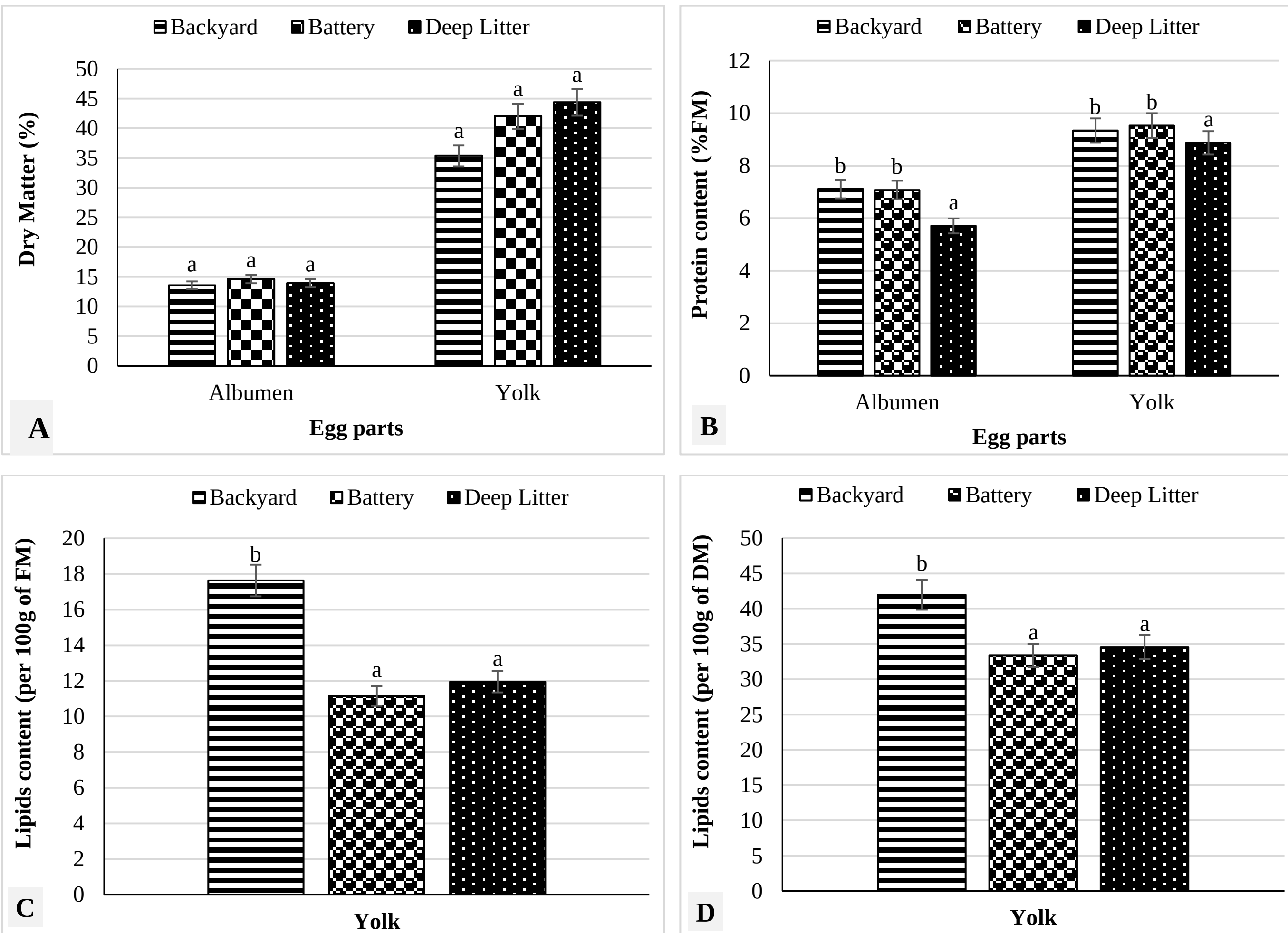

Figure 5. Chemical characteristics of layer hen eggs according to production systems in the city of Ngaoundéré, Cameroon from August to October 2020. A: Dry Matter B: Protein, C: Lipids (per 100g FM: fresh matter), and D: lipids (100g DM: dry matter). [a,b,c]: Values with the same letter are not significantly different per parameter (p > 0.05).

DISCUSSION

The predominance of men (90.9%) in modern poultry farming recorded in the current study contradicted with the general trends of a study by Fotsa et al. (2007) concluding that family poultry farming was mostly (56.6%) carried out by women. This was also the case for Moula et al. (2012) whose work in village poultry farming in Bas-Congo in the Democratic Republic of Congo revealed that in 42.9% of the families visited, hen rearing was exclusively carried out by women, compared to only 15.6% of men. Similar results were reported by Pousga (2009), and Djitie et al. (2015), who indicated that village or family poultry farming is mainly considered as an activity for women and children. Such discrepancy can be due to traditions in the Ngaoundéré region that all family burdens should be supported by men and women are not required to be economically active. Modern poultry practice also requires a strong financial and managerial involvement which cannot easily be supported by women.

Poultry farming and trade have been the main activities of the respondents. Agriculture as the second dominant activity is an integral part of the lives of urban populations. These observations contrast with previous studies (Ekue et al., 2002; Sonaiya and Swan, 2004; Djitie et al., 2015) who argued that in African family poultry farming is rarely the household livelihood, but represents one of the many integrated and complementary activities that contribute to its overall well-being. These observations in the case of the present study would be justified by the fact that modern poultry farming is an income-generating activity, which helps to support the farmers. All animals were housed and buildings were made of long-lasting materials that provide good protection for the animals against bad weather, theft, and predators. These observations contrasted to those reported by Pousga (2009) and Moula et al. (2012) who indicated that in rural areas, 80% of poultry houses were built in the traditional style with old sacks (73%) or straw (7%). They also reported that in some cases, chickens have no shelter and spend the night perched on trees. The same observations were made by Fotsa et al. (2007); Moula et al. (2012) and Djitie et al. (2015) whose husbandry practices seemed to be a little more serious. In their studies, the farmers said that they locked up chickens in the evening and only opened them in the morning. Badudi and Ravindra (2002) and Hassen et al. (2007) in Botswana and Ethiopia respectively, reported that a few farmers could provide habitat for their animals. However, the results of the present study were in line with a study by Ayssiwede et al. (2011) who noted that in the Gambia, only 10% of livestock keepers had acceptable shelters. Kondombo (2007) and Ouedraogo et al. (2015) in Burkina Faso indicated an improvement in the use of improved housing as the sub-sector has been supported by several programs and projects.

Feeding was entirely the responsibility of the farmers. In this regard, most farmers bought the feed directly from companies while others made their own feed formulation. The drinkers, feeders, and nesting boxes were adapted to modern poultry farming. Results of the present study were in contrast to studies by Sonaiya and Swan, (2004) and Ayssiwede et al. (2011) in poultry farming of a village in Zimbabwe, indicating that in 39.58% of poultry farms, a mixture consisting mainly of maize waste and barley grains was fed to the animals. This observation was also made in family poultry farming by Fotsa et al. (2007) in the Cameroonian plateau, Djitie et al. (2015) in Vina Division, Adamaoua region, Cameroon, and Ouedraogo et al. (2015), in Ouagadougou, Burkina Faso. According to them, the current chicken feeding system was based on rambling consisting of pigeon food, insects, and other items.

The mortality rate was 1-10% per year for 30.3% of the farmers. The low mortality rate can be explained by the fact that battery and deep litter poultry farming systems were more closely monitored than in the traditional system. These observations corroborated those reported for chickens raised in stations (9.8%, Diagne, 2012). The selling price of broilers at 45 days of age and of re-laying hens at the end of the laying period varies from 5 to 6 USD as a function of chicken weight and size, as well as market demand. This was in line with the observation made by Djitie et al. (2015). The most frequently cited constraints were the high cost of feed as well as lack of financial support, feed supply, and security. These constraints were in contradiction with those reported in village poultry farming in numerous studies generally in developing countries, such as a study by Kugonza et al. (2008) in Uganda, Raach-Moujahed et al. (2011) in Tunisia, Bett et al. (2012) in Kenya, Moula et al. (2012) in the Democratic Republic of Congo and Djitie et al. (2015) in Cameroon, who observed that the most frequently encountered constraints were diseases, predators, lack of monitoring and theft. In the case of the present study, it could be explained by the fact that the animals were confined in large numbers, which increases their feed consumption. Another important factor, stealing, occurred since most poultry farms were housed in a peri-urban area with poor security.

Egg weights from the backyard system (43.50 g) were lower than those from the battery (58.19 g) and deep litter (63.51g) systems. These differences in weight can be explained by genetic diversity, rearing systems, feed, age of the hen, climactic changes, and vegetation (Egahi et al., 2013). It could also be due to the fact that backyard hens are mainly characterized by a small size, which produces smaller eggs in contrast to layers, which are hens selected only for laying. Results of the present study were similar to those obtained by Keambou et al. (2009) in Cameroon, who reported an average egg weight of 44.49 g for local hens, compared to the commercial breed. Several authors (Dafaalla et al., 2005; Fotsa et al., 2007), reported similar weights to those obtained in the present study ranging from 37.95 to 44.9 g on local eggs in the West and Central Africa. Dahloum et al. (2015) in Algeria working on commercial hens, recorded results close to observation (61.54 g) on egg's weight from the battery and deep litter systems in the present study. On the other hand, Moula et al. (2012) reported average weights between 50.23 and 54.32g on local hen eggs in lower Kabylia. Depending on the genetic variability, the weight of local hen eggs is in the range of 27-54.7g (Alkan et al., 2013). There was also a significant difference in density, with the lowest value observed in backyard eggs (1.05 ± 0.06), compared to the battery (1.09 ± 0.06) and deep litter (1.10 ± 0.08) systems.

The diameter and height average of eggs from backyard systems were lower than those of eggs from the battery and deep litter systems. These observations were higher than those recorded by Fayeye et al. (2005) in Morocco, Keambou et al. (2009) in West Cameroon, but lower than those reported by Samandoulougou et al. (2016) in Burkina Faso, Djitie et al. (2020), in the city of Iasi in Romania. The values recorded in the present study were higher than those reported by Salifou (2007) in Dakar on commercial eggs. All these variabilities in egg size could be related to breeds, the laying period of the hen, and the protein content of the feed. They could also be due to genetic type (Küçükyılmaz et al., 2012), and geographical areas (Athias, 2003) that affect egg weight, size, and even color (Sauveur, 1988). Shape indexes recorded in the present study were higher than those of other studies. Markos et al. (2017) reported the shape indexes of 66.5 to 71.3% for local hen eggs, Keambou et al. (2009) found values close to 73% for eggs from rural families, and Samandoulougou et al. (2016) estimated the range of 72-75% for commercial breed eggs. According to King'ori (2012), size, age, health status of the hen is among the factors that can strongly influence the egg shape index. Backyard eggs showed a significantly lower egg volume of 41.75, compared to those from deep litter and battery systems. This lower egg volume observed in backyard eggs could be attributed to the lower egg weight, diameter, and height (Jessy et al., 2016). These results corroborate those reported by Kanagaraju et al. (2013) on quail, who indicated that egg volumes vary between phenotypes. Observations on yolk quality highlighted that eggs from backyard systems contained more yolk correlated with the higher diameter and yolk proportion. The same trends were observed by several authors on the assessment of eggs from local and commercial breeds (Alewi et al., 2012; Zaaboube and Benrahou, 2014). However, higher egg volumes than in the present study were observed in different agro-ecological zones in Ethiopia (Melesse et al., 2010; Melesse et al., 2013) on eggs from rural hens. Although eggs from deep litter and battery systems showed no significant difference in yolk height and index, they were higher, compared to those from backyard eggs. The average albumen weight of eggs from deep litter and battery systems was higher than that from the backyard. Similar values to those of eggs from deep litter and battery systems were observed by Moula et al. (2012) with eggs from Isa Brown and CoqArd breeds. Lower weights within the range of 30.92 and 33.18 g were found in eggs from the White Leghorn strain (Sreenivas et al., 2013). They reported significant relationships between albumen and whole egg weights. Albumen percentage and height were higher in backyard eggs, compared to eggs from the battery and deep litter systems, the opposite was recorded for diameter.

Haugh unit did not differ significantly for deep litter and battery eggs, which were also higher than the value obtained with backyard eggs. This would be justified by the fact that backyard eggs were collected from the market, and therefore the age could be different, yet eggs from deep litter and battery systems were of the same age. Haugh units from the present study were higher than that reported by Melesse et al. (2013) in Ethiopia, Egahi et al. (2013) in Nigeria in local hens. The highest shell weight value was observed in eggs from deep litter and battery systems. Similar observations were made by Moula et al. (2012) who reported that the shell weight of eggs from Isa Brown hen was higher than that of the traditional breed. Several authors reported that this trait is strongly related to the weight of the whole egg (Alipanah et al., 2013; Sreenivas et al., 2013). The same remark was made by Dahloum et al. (2015) in Algeria, according to whom the commercial layer hen strains had a higher shell weight compared to the local breed with normal feathers. The values recorded in the present study could be explained by the fact that the feeding of the commercial breed of hens was optimal and generally met the required standards, whereas, backyard hens were free-range. Observations made for shell proportions revealed that they were around 9.85%, 10.42%, and 10.45% for battery, deep litter, and backyard systems eggs, respectively. Previous works by El-Safty et al. (2006) on bare-necked heterozygous hens and local hens in Egypt and Djitie et al. (2020) on backyard eggs in Romania indicated lower values than values obtained in the present study. However, Samandoulougou et al. (2016) observed higher values of shell proportions in Burkina Faso. Egg shell thickness obtained in the current study was close to that recorded by Djitie et al. (2020) revealing similar values to those of eggs from deep litter and battery poultry farming systems, but lower than those of backyard eggs.

Egg yolk pH was acidic while egg albumen pH was basic regardless of the farming systems considered. A significant increase in pH was observed between deep litter, battery, and backyard systems. These results were in agreement with those mentioned by Dahloum et al. (2015) in Algeria and Samandoulougou et al. (2016) in Burkina Faso who mentioned values of 5-6 and 8-9, respectively, for yolk and albumen in local and commercial hens. This increase could be justified by the fact that backyard eggs were collected from rural families and their production date associated with the feed ingredients and feeding program while eggs from the battery and deep litter poultry farming systems were of the same age and standardized feeding program. This variation of pH could also be due to the genetic type and rearing system. Yolk contained more dry matter and lipids than the albumen in all three systems, except for the protein content where the reverse case was recorded. Results obtained for eggs from deep litter and battery systems were in line with those found by Nys and Sauveur (2004) in France on layer eggs, Samandoulougou et al. (2016) in Ouagadougou on eggs from improved breeds, Djitie et al. (2020) in Romania on from local hens eggs. The lipid content of backyard eggs was higher than that of deep litter and battery systems eggs. These observations were contrary to those of AEB (2006) on eggs from rural families in the United States of America, which reported a value of (52.9%) and Samandoulougou et al. (2016), who recorded 32.76% for eggs from local hens in Burkina Faso. This difference in results could be explained by genetic type, rearing systems, environment, and animal feeding. Given the very low lipid content (0.2-0.4%) in egg albumen (Sauveur, 1988; AEB, 2006), the effect of production systems on lipid content has not been studied.

The yolk dry matter content of battery and deep litter system eggs was higher than that obtained in backyard eggs. The yolk dry matter recorded was higher than that reported by Arzour (2006) in Algeria (26%) and Samandoulougou et al. (2016) in Burkina Faso (28.68%) on improved breed eggs. Results obtained were also in contrast to the work of Djitie et al. (2020) which showed that local breed eggs contained more dry matter than commercial breed eggs. The protein content of yolk and albumen was similar between the backyard and battery eggs but higher than values recorded for the deep litter system. This observation contrasted with those of Lahouari et al. (2015) who recorded the values of 13.07% and 12.61% for eggs from commercial and local breeds, respectively. This difference in results could be explained by the influence of breed, age, and diet on the egg protein content (Sauveur, 1988; Nys and Sauveur, 2004).

CONCLUSION

In conclusion, modern poultry farming was generally carried out in poorly developed deep litter systems. Poultry farmers were not trained for this activity despite the need for real intensive training and improvement of the modern poultry farming sector in the area. Generally, eggs from deep litter systems exhibited better characteristics in terms of weight and freshness, eggs from local hens showed better characteristics in terms of chemical or nutritive elements and were, therefore, more recommended.

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Authors’ contribution

FDK and CT designed the study, interpreted the data, and drafted the manuscript. MB was involved in data collection and manuscript preparation. RMRR took part in the study design, preparation, and critical checking of the manuscript.

Competing interests

The authors declare that there is no conflict of interest in the outcome of this research.

Ethical consideration

Ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/submission, and redundancy) have been checked by the authors before the submission. The final results of the statistical analysis have been also checked and confirmed by all authors.

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