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Evaluation of Zootechnical Performance of Muscovy Ducks in South Benin

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ABSTRACT

Studies on the zootechnical performance of Muscovy ducks are scarce in Benin. The current study aimed to evaluate the performance of these ducks in a controlled environment for a better valorization of potentialities. Data were collected from 193 ducks for growth performance, 30 ducks for egg-laying performance, and 71 eggs for egg characteristics of Muscovy ducks in South Benin. The ducks were raised in controlled conditions. At hatching, male and female ducks had similar weights and body measurements. From week 2 to week 68, males had significantly higher weight than females. Males had higher initial specific growth than females (0.52 vs 0.63 per week), while females were older than males regarding age inflection point (33.10 vs 25.98 weeks). In addition, males had longer bodies, wider thoraces, and longer tarsus than females. Regarding the wingspan, the difference between males and females was observed from week 8, with higher values in males. Individual feed intake and feed conversion ratio increased as the ducks grew older. In the first week, the individual feed intake was 20.08 g per day, and the feed conversion ratio was 1.51. After 20 weeks of age, Muscovy ducks consumed 136 g daily with a high feed conversion ratio of 26. The age of the first egg of Muscovy duck was 6.17 months, and the average number of eggs laid per brooding was 15.37 eggs. The brooding duration was 35.63 days, with a hatching rate of 73.06%. The duckling's survival rate at hatching was 95.28%, of which 97.47% were weaned. The average weight of a duck egg was 63.56 g, and that of the shell was 8 g, while albumen and yolk amounted to 30.01 g and 23.86 g, respectively. Duck eggshell dominant color was white (60.5%), followed by dirty white (26.31%), and finally brown (13.64%). These results on the zootechnical performance of the Muscovy duck can be considered a reliable basis for this species' potential improvement in South Benin.

Keywords: Average daily gain, Benin, Feed conversion ratio, Muscovy duck, Weight, Zootechnical performance

INTRODUCTION

Muscovy duck (*Cairina moschata*, Linné, 1758) is a domestic species of the Anatidae family, derived from the Musk duck, native to South America (Teulier, 2010). It is from a large family of aquatic palmipeds with webbed feet (Anatidae) and is bred worldwide for egg and meat production. Their down, feathers and fatty liver are well-sold products (Guy et al., 2006). *Cairina moschata* is the most common species in Sub-Saharan Africa and is known for its great zootechnical performance and high resistance to various avian pathogens (Akpla, 2013; Houessionon et al., 2020). In Benin, its breeding is widespread in traditional poultry farming throughout the country, particularly in the South. Despite its importance in traditional poultry farming, Muscovy ducks are fewer in number and have a lower contribution to food security than other poultry species. Therefore, an update on this species' breeding has been carried out in the three agroecological zones of southern Benin to diagnose bottlenecks that limit this speculation development to set up an improvement strategy (Houessionon et al., 2020).

The update revealed that duck breeding modes differ between the three agroecological zones of southern Benin and within each of them, making it difficult to formulate recommendations. Duck farm typology has indicated three types of duck breeding in south Benin. Type 1 is characterized by a traditional system based on ducks' scavenging and the absence of health monitoring. Breeding type 2 includes a semi-improved family system, and breeding type 3 is characterized by the dominance of livestock buildings and rangelands where ducks are reared free range (Houessionon et al., 2019). The characteristics of these three breeding types are different, and integrated proposals have been formulated for each type (Houessionon et al., 2019). The implementation of proposals will then improve ducks' productivity but not their genetic potential. Given this, an evaluation of Muscovy duck's zootechnical performance is necessary to have a reliable basis for effective selection or crossbreeding program. The general objective of the study was to assess the zootechnical performance of Muscovy ducks in a controlled environment for a better estimation of their potential while minimizing the effect of environmental factors. In particular, the present study aimed to assess body weight performance and morphometric traits of Muscovy ducks according to sex, feed intake, and feed conversion ratio of this species, and finally, laying performance and egg characteristics of Muscovy duck.

MATERIAL AND METHODS

Ethical approval

Ducks in the current study were raised and treated according to the letter N° 23-2017/LBATV/DPSA/Se of 16 March 2017 of the Laboratory of Animal Biotechnology and Meat Technology of the University of Abomey-Calavi (Benin), approved by the Animal Welfare Committee of Benin.

Study area

The experiment was carried out at the poultry station of the Laboratory of Animal Biotechnology and Meat Technology of the University of Abomey-Calavi in South-Benin, precisely in the Township of Abomey-Calavi, district of Togba, area of Agori, at 6° 42' 6'' North longitude and 2° 32' 4'' East latitude. The Township of Abomey-Calavi is bounded to the North by the Township of Zè, to the South by the Atlantic Ocean, to the East by the Townships of Sô-Ava and Cotonou, to the West by the Townships of Tori-Bossito and Ouidah. It has an area of 539 km^2 and a population of more than 656,358 inhabitants in 2013 (INSAE, 2015). The climate is of subequatorial type with two rainy and two dry seasons. The major rain is from April to July, and the minor is from September to November. These seasons are separated by two dry seasons.

Breeding mode

The zootechnical characteristics study was carried out on Muscovy ducks (*Cairina moschata*). The breeding stocks were 2 males and 10 females bought from the three agroecological zones of southern Benin (depression, Ferralsols, and fishery), where consanguinity was not recorded, and other breeds were not used for crossbreeding. They were 5-7 months old, and the females had not yet started to lay eggs. After a month of quarantine, these reproducers were put together and reared in a coop with pens having access to a water pond. They were housed in a coop measuring 15 m² divided into three pens of 5 m² using wire netting in which 20 ducklings born during the same week were reared. The house roof was made of corrugated aluminum sheets. The floor was cemented, and the walls were 90 cm in height, topped with wire mesh. The inside of the pens was heated to 33°C by brooders made of jars filled with charcoal every evening until ducks aged three weeks. The litter was made of 3 cm wood chips. A footbath was installed on the floor at each lodge entrance for foot disinfection. Each lodge is extended by a courtyard of 300 m². Feeders, drinkers, and nest boxes were installed in the coop.

Matings were performed daily at random, and each duck laid, incubated, and hatched her eggs. At hatching, ducklings were given an identification number and were recorded in the database with their mother's name, parity number, and hatching date.

Three feeds were distributed during the animal breeding, including a starter feed, a growing feed, and a laying feed. For all the ducks, the starter feed was used for eight weeks and was followed by the growing feed, from week 8 to the laying onset at month 6. The laying feed was served to birds from 6 months onward. Feeds given to animals were bought in the commerce, and their nutritional values can be seen in Table 1.

The study set up a health and medical prophylaxis program for health monitoring. Sanitary prophylaxis consisted of hygiene rules and strict observance. The drinkers were washed daily, and the litter was renewed when altered. A footbath containing 5% cresyl disinfectant solution was placed at the coop entrance. As for medical prophylaxis, preventive treatments against infections and

coccidiosis were performed using Alfaceryl® (ALFASAN-Veto Service SA, Benin), erythromycin thiocyanate, oxytetracycline + vitamins A, D3, E, K, B1, B6, B2, B12, PP, C) and Amprolium® (LAPROVET-Veto Service SA, Benin) and Amprolium chloridrate in powder form. Ducks were vaccinated against Newcastle disease at 3 weeks with the second dose at two weeks later (CEVA® NEW L: A lentogenic strain of LaSota by oral route). The samples were dewormed every two months from the weaning against gastrointestinal parasitosis (Alfamisole®: levamisole) and also received a vitamin complex (Amin'Total®: vitamins, amino acids, and trace elements) by oral route. Oxytetracycline 50% (ALFASAN-Veto Service SA, Benin) was the most commonly used antibiotic for possible infectious diseases.

Table 1. Nutritional values of diets in Muscovy ducks

Items	Starter (1-8 weeks)	Grower (9-24 weeks)	Laying (>24 weeks)
Energy (kcal/kg)	2900	2800	2500
Crude protein (%)	21	19	18.5
Lysine (%)	1.1	1	0.9
Methionine (%)	1	0.44	0.44
Calcium (%)	1.08	1.01	3.5
Total phosphorus (%)	0.55	0.5	0.5
Crude ash (%)	7.37	7.12	13
Crude cellulose (%)	2.5	3.32	-
Sodium (%)	0.2	-	-
Crude fat (%)	5.54	5	4.5
Flavomycin (%)	0.007	0.007	0.005
Chloride (%)	0.19	-	-

Data collection and processing

Body weights, body length, tarsus length, thoracic perimeter, and duck wingspan were measured at hatching (P0), 2 weeks (P2), and 4 weeks (P4) of age and then once a month until 68 weeks of age. The ducks were weighed individually in the mornings before food service, with KERN brand balances of 1g, 5g, 10g, and 50g of precisions, respectively, for weights of 100g, 600g, 1000g, and 5000g. Average daily gain (ADG) was then calculated as t1 (0 to 12 weeks), t2 (12 to 24 weeks), t3 (24 to 36 weeks), t4 (36 to 48 weeks), and t5 (48 to 60 weeks). The food leftovers were recorded daily. The growth curve parameters were calculated using the Gompertz equation (Laird et al., 1965) according to the following formula: $W_t = W_0\, e^{L(1-\exp(-Kt))\,/\,K}$

Where W_t is the weight recorded at t age, W_0 denotes the estimated birth weight, L signifies the initial specific growth rate $(1/W^t) \times (dW_t/dt)$ when $t \rightarrow 0$), K is the maturity rate and TI, the age at inflection point corresponding to the period of the maximum growth. The following formula calculates the age inflection point.

$$TI = \left(\frac{1}{K}\right)\ln\left|\frac{L}{K}\right|$$

These growth curve parameters were estimated from the nonlinear regression using the NLIN procedure and the SAS Marquardt method taking into account the weight by age from hatching at the age of 68 weeks.

Feed intakes were obtained by the difference between the food quantities served and the leftovers of the day. The feed conversion ratio (FCR) was calculated by dividing an animal's feed intake by its average daily gain over a given period. The feed conversion ratio (FCR) was calculated for the first 20 weeks.

Concerning the laying performance, the age of the first egg, the number of eggs laid, the number of eggs brooded, the number of eggs hatched, the brooding duration, the number of alive ducklings at hatching, the number of weaned ducklings and the interval between two successive broods were recorded per duck for a total of 30 ducks. Annual egg production was determined by considering the total number of eggs laid by a female in one year from the first laid egg.

As for egg characteristics, the weight of the egg, shell, albumen, and yolk weight were recorded on 71 eggs. The egg variables were weighed using a KERN brand balance of 0.1 mg of precision with a capacity of 220 g. The eggshell color (white, brown, cream, tinted, or other) was also recorded.

Statistical analysis

The Statistical Analysis System software (SAS, 2013) was used to analyze data. A linear model with sex fixed-effect was adjusted to data on weight, average daily gain, and body measurements for analysis of variance. The F-test was used to determine the significance of the sex effect on each variable. The proc corr procedure was used to calculate correlations between the egg characteristics and those between the body measurements taken at 36 weeks of age for all ducks (all sexes combined) and by sex. The proc means procedure was used to calculate averages of individual feed intake and weekly feed conversion ratio as well as those of egg laying performance. Finally, the proc freq procedure was used to calculate the color class frequencies of eggshells. The means were compared using the student's t-test and the frequencies were compared paired by the Z-test. A significant level of $p < 0.05$ was used for all comparisons in both tests.

RESULTS

Body weight performance

At hatching, males and females had similar weights. From week 2 to week 68, males' weight was significantly higher ($p < 0.05$) than that of females (Figure 1). At the end of the experiment, the males' weight amounted to 3490 g, compared to 1900 g for females. The average daily gains for males were significantly higher than those of females ($p < 0.05$, Table 2). As for growth curve parameters, the maturity rate was similar for males and females (Table 2). However, males had higher initial specific growth than females, while females were older than males at the age inflection point.

Morphometric traits

At the hatching, body length, thoracic perimeter, and tarsus length of females and males were similar. From week 2 to week 68, males had a longer body, a wider thorax, and a longer tarsus than females ($p < 0.05$). Regarding the wingspan, the difference between males and females was observed from week 8 in favor of the males ($p < 0.05$). The growth curve of body length, the thoracic perimeter, the tarsus length, and the wingspan of females and males from hatching to week 68 are respectively shown in Figures 2-5.

Regardless of the sex, the correlations between body length, thoracic perimeter, tarsus length, live weight, and wingspan were positive and significant in all ducks ($0.699 \leq r \leq 0.944$, $p < 0.05$). Each variable was positively and significatively associated with the other ones. The correlations between the morphometric measurements of Muscovy ducks of both sexes are presented in Table 3. In females, the correlation between thoracic perimeter and live weight was positive and significant ($r = 0.415$, $p < 0.05$), but the correlations between the other body measurements were not significant. In males, wingspan had no significant correlation with other body measurements. The correlation between thoracic perimeter and body length also was insignificant. A low correlation was observed between body weight, body length, and tarsus length ($0.305 \leq r \leq 0.344$, $p < 0.05$) on one hand and between thoracic perimeter, tarsus length, and live weight ($0.355 \leq r \leq 0.432$, $p < 0.05$) on the other hand. In males, body length was significantly correlated with tarsus length. The correlations between the morphometric measurements of 36-week Muscovy ducks (female and male) reared in a station in southern Benin are presented in Table 4.

Feed intake and feed conversion ratio

The individual feed intake and the feed conversion ratio increased overall with age (Table 5). In the first week, individual feed intake was 20.08 g per day, and the feed conversion ratio was 1.51. After 20 weeks of age, the ducks consumed 136 g daily with a high feed conversion ratio of 26.

Laying performance

Muscovy duck's age at first egg was 6.17 months, and the average number of eggs laid per brood was 15.37. The brooding duration was 35.63 days, with a hatching rate of 73.06%. Ducklings' viability rate at hatching was 95.28%, of which 97.47% were weaned. The hatch-weaning mortality rate was 2.53%. The brood interval was 101 days, and the annual egg production was 47.54. The laying performance of Muscovy ducks reared in a station in South Benin is presented in Table 6.

Egg characteristics

The average egg weight of the duck was 63.56g and the shell weight was 8 g representing 12.59% of the egg weight. The albumen and the yolk weighed 30.01 and 23.86g or 47.22% and 37.54% of the egg weight, respectively. The egg characteristics of Muscovy ducks are presented in Table 7. Although there was an insignificant correlation between yolk weight and albumen, all other egg characteristics were highly correlated with each other ($p < 0.05$, Table 8). The dominant eggshell color was white (60.5%), followed by dirty white (26.31%), and brown (13.64%, Table 9).

Table 1. Nutritional values of diets in Muscovy ducks

Items	Starter (1-8 weeks)	Grower (9-24 weeks)	Laying (>24 weeks)
Energy (kcal/kg)	2900	2800	2500
Crude protein (%)	21	19	18.5
Lysine (%)	1.1	1	0.9
Methionine (%)	1	0.44	0.44
Calcium (%)	1.08	1.01	3.5
Total phosphorus (%)	0.55	0.5	0.5
Crude ash (%)	7.37	7.12	13
Crude cellulose (%)	2.5	3.32	-
Sodium (%)	0.2	-	-
Crude fat (%)	5.54	5	4.5
Flavomycin (%)	0.007	0.007	0.005
Chloride (%)	0.19	-	-

Table 2. The body weight of Muscovy ducks reared in South-Benin

Variable	Female			Male			ANOVA
	Number	Average	SE	Number	Average	SE	
ADGT1 (g/j)	102	15.15	0.37	79	24.67	0.42	***
ADGT2 (g/j)	102	14.17	0.38	79	22.17	0.42	***
ADGT3 (g/j)	93	19.61	0.28	72	38.22	0.30	***
ADGT4 (g/j)	95	20.56	0.40	79	37.90	0.46	***
ADGT5 (g/j)	83	20.27	0.46	71	38.17	0.63	***
K (1/week)	102	0.13	0.01	79	0.15	0.01	NS
L (1/ week)	102	0.52	0.04	79	0.63	0.05	*
Ti (week)	102	33.10	2.34	79	25.98	2.66	*

SE: Standard error; ADGT: Average daily gain of the term; K: Maturity rate, Ti: Age at an inflection point; L: Initial specific growth; NS: Not significant, */***: $p < 0.05$.

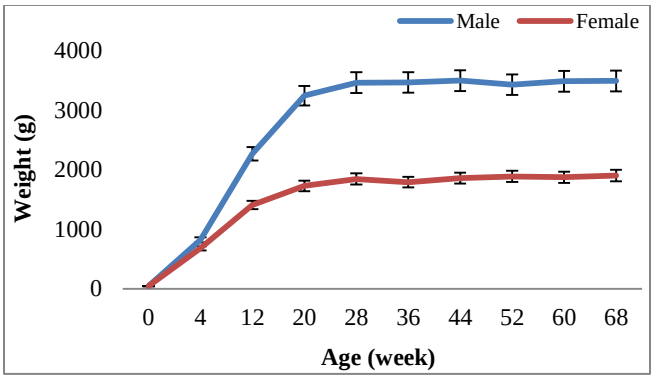

Figure 1. Body weight performance of Muscovy ducks according to sex

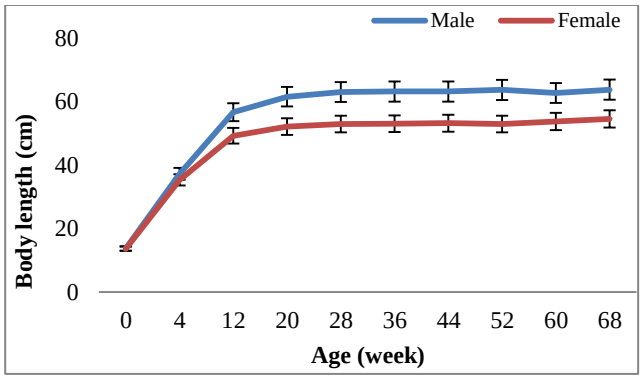

Figure 3. Body length of Muscovy ducks according to sex

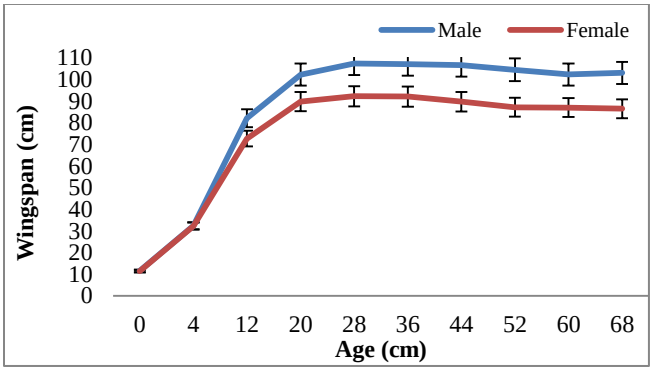

Figure 2. Wingspan of Muscovy ducks according to sex

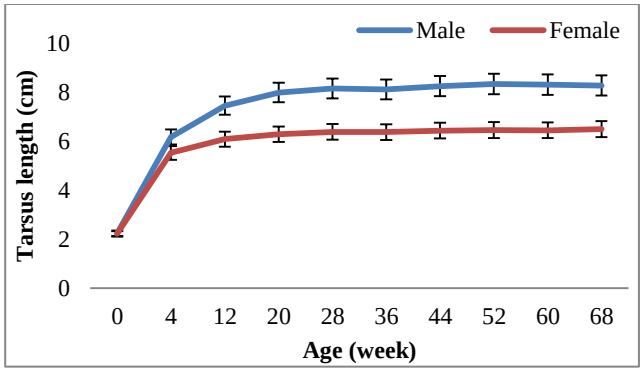

Figure 4. Tarsus length of Muscovy duck according to sex

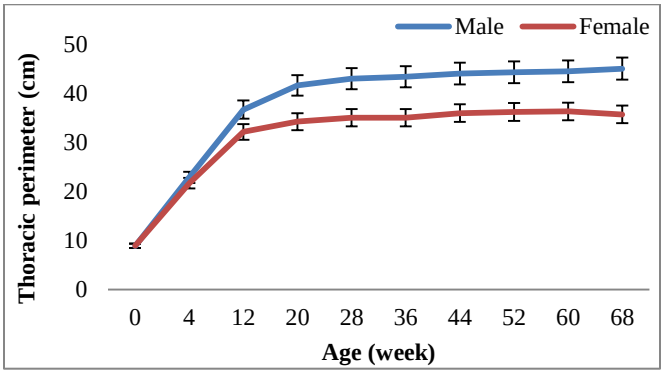

Figure 5. The thoracic perimeter of Muscovy ducks according to sex

Table 3. Correlations between the morphometric measurements of Muscovy ducks reared in South Benin

Variables	Body length (cm)	Tarsus length (cm)	Live weight (kg)	Thoracic perimeter (cm)
Wingspan (cm)	0.717***	0.705***	0.764***	0.699***
Body length (cm)		0.894***	0.895***	0.872***
Tarsus length (cm)			0.943***	0.918***
Live weight (kg)				0.944***

*** : $p < 0.05$

Table 4. Correlations between morphometric measurements of females (above the diagonal) and of males (below the diagonal) of Muscovy ducks reared in South Benin

Variables	Wingspan (cm)	Body length (cm)	Tarsus length (cm)	Live weight (cm)	Thoracic perimeter (cm)
Wingspan (cm)	1	0.183 NS	-0.094 NS	0.050 NS	-0.039 NS
Body length (cm)	0.01NS	1	-0.069 NS	-0.110 NS	0.133 NS
Tarsus length (cm)	-0.11 NS	0.449**	1	0.198 NS	0.131 NS
Live weight (cm)	0.20 NS	0.344*	0.30572*	1	0.415**
Thoracic perimeter (cm)	-0.13 NS	0.18 NS	0.355*	0.432*	1

NS : $p > 0.05$; * / ** : $p < 0.05$.

Table 5. Individual feed intake and feed conversion ratio of Muscovy ducks reared in South Benin

Age (week)	Number	Individual feed intake		Feed conversion ratio	
		Average (g)	Standard Deviation	Average (g)	Standard Deviation
1	56	20.08	10.36	1.51	0.78
2	56	49.81	15.71	3.74	1.18
3	56	63.14	13.38	1.88	0.40
4	56	79.14	17.53	2.36	0.52
5	56	92.29	18.80	3.31	0.67
6	53	100.30	20.17	3.60	0.72
7	49	103.96	21.28	3.73	0.76
8	47	103.93	19.30	3.73	0.69
9	41	104.28	24.49	10.89	2.56
10	39	104.00	23.47	10.86	2.45
11	28	107.60	34.54	11.23	3.61
12	28	110.92	50.17	11.58	5.24
13	26	110.29	39.28	12.06	2.36
14	21	108.30	34.89	15.31	2.10
15	21	104.58	33.93	15.69	2.04
16	16	111.92	17.73	16.73	1.07
17	14	109.49	24.54	20.89	4.68
18	14	100.77	27.54	19.23	5.26
19	11	127.88	23.71	24.40	4.53
20	7	136.31	26.10	26.01	4.98

Table 6. Laying performance of 24 to 26-month-old Muscovy ducks reared in South-Benin

Variables (N=30)	Average	Standard Deviation	Coefficient of variation (%)
Age at first egg (months)	6.17	0.38	6.15
Number of laid eggs	15.37	4.25	27.69
Number of brooded eggs	15.37	4.25	27.69
Brood duration (day)	35.63	2.50	7.01
Number of hatched eggs	11.23	4.01	35.74
Number of alive ducklings	10.70	4.15	38.82
Number of weaned ducklings	10.43	4.12	39.45
Annual eggs production	47.54	21.96	46.19
The interval between two broods (day)	101.11	49.12	48.58

Table 7. Egg characteristics of 7-month-old Muscovy ducks reared in South Benin

Variable (N=71)	Average	Standard deviation	Coefficient of variation (%)
Egg weight (g)	63.56	6.28	9.88
Shell weight (g)	8.09	0.69	8.54
Albumen weight (g)	30.01	3.34	11.14
Yolk weight (g)	23.86	4.38	18.35

Table 8. Correlations between variables of egg characteristics (egg weight, shell weight, and albumen weight) of Muscovy ducks reared in the South Benin

Variable	Shell weight (g)	Albumen weight (g)	Yolk weight (g)
Egg weight (g)	0.744^{***}	0.629^{***}	0.801^{***}
Shell weight (g)		0.415^{***}	0.641^{***}
Albumen weight (g)			0.152^{NS}

NS: $p > 0.05$; ***: $p < 0.05$.

Table 9. Eggshell color of Muscovy ducks reared in South Benin

Variables	Number	Frequency (%)	Confidence interval
White	40	60.5^{a}	15.15
Dirty white	17	26.31^{b}	20.93
Brown	9	13.64^{b}	22.42

Percentages followed by different superscript letters differ significantly at the threshold of 5%

DISCUSSION

Body weight performance and morphometric traits

At hatching, males and females had similar weights, but from week 2, males were heavier than females until week 68. These ducks grow gradually from hatching to adulthood, and males' live weight is almost double that of females. At the end of the experiment in the present study, males weighed 3490 g, compared to 1900 g for females. This difference must be from the genetic and hormonal origin and is observed in many species. Sex hormones improve conformation and growth potential depending on sex (Ismoyowati et al., 2017). In Nigeria, Oguntunji and Ayorinde (2014) found this influence of sex on the Muscovy duck's weight. In an extensive system, they report a live weight of 2640 g in males and 1600 g in females. According to Bati (2017), sexual dimorphism is a remarkable trait in Muscovy ducks. His study on the zootechnical performance of black, white-black, white, and gray varieties of Muscovy ducks in Congo indicated this difference in weight. Similar to the findings of the present study, Bati (2017) reported a significant difference in the second week of age, thereby becoming more important throughout birds' growth, indicating a faster growth rate in males. Yakubu et al. (2011) also reported similar results to the present study in Nigeria. Similar results are observed in previous studies on other poultry species such as chickens, guinea fowl, and geese. Indeed, Youssao et al. (2012) and Tougan et al. (2013) reported the influence of sex on the birds' weight in various studies on local poultry populations of *Gallus gallus* species. Likewise, Dahouda et al. (2008) and Uhlířová et al. (2018) also obtained similar results in guinea fowl and geese, respectively.

Females were older at the inflection point than males (33.10 vs. 25.98 weeks). This age indicates when animals have reached their maximum growth (Youssao et al., 2012), which is an ideal age as the cost/growth ratio is optimal, and it is advisable to take out fattening animals. Most often, the age at the inflection point corresponds to puberty. Generally, animals reach this point 2/3 of their adult weight. Growth in the majority of Muscovy ducks is relatively rapid in the beginning phase (from week 1 to week 12), which corresponds to the accelerated growth phase. A duckling born with a weight of 44.36 g multiplies its weight by 10 after 4 weeks. According to Teulier (2010), Muscovy ducklings have exponential growth during the first 4 weeks of their life. The results of the present study are in line with other poultry studies, indicating that local chickens of *Gallus gallus* species in free-range farming have good growth during the first 12

weeks of age (Youssao et al., 2009; Akouango et al., 2010). Muscovy ducks' weight changes gradually and stabilizes at the finishing period when adult weight is reached, which corresponds to the slow growth phase. In addition, weight stabilizes with age and does not increase following the normal bird growth curve. This stabilization is explained in females by the laying onset, which results from the use of the ingested feed for egg production to the detriment of muscle growth. In males, the age inflection point corresponds to puberty. This is the period when they start mating females, or they seek to demonstrate their dominance in the backyard. In the experiment, this period is characterized in males by physical and recurring confrontations and chases in the courtyard, causing bodily injuries. These physical efforts cause daily considerable energy loss that justifies body weight stabilization after the age inflection point. Djitie et al. (2014) made similar observations reporting that in the reproductive phase or beyond 24 weeks of age, weight growth is almost null and does not change significantly.

Body weight performance in the present study is better than those reported by Oguntunji and Ayorinde (2014) on adult male and female Muscovy ducks, and this difference in weight is related to the breeding system. On the other hand, in an intensive system in France, for example, Muscovy ducks are heavier than the males and females in the present study. Thus, the live weight of force-fed Muscovy ducks is 6393 g, and that of lean Muscovy ducks is 5418 g (Chartrin et al., 2006; Baeza et al., 2013). This difference in weight must be justified by genetic selection. No selection was performed on the Muscovy ducks in the present study. This explains the high coefficients of variation values of body weight performance of the species in the three agroecological zones of southern Benin, from which originate parents.

On the other hand, the European Muscovy duck has been selected for lean meat or fatty liver production. The results of Larzul et al. (2006) on the zootechnical performance of Muscovy ducks, Pekin ducks, and their crosses (Hinny and Mulard) also showed a significant difference in data on weight. In other words, Muscovy ducks (6520 g) were the heaviest and Pekin ducks the lightest (4095 g), and the two different genetic types of Hinny and Mulard were intermediate (5714 g and 5774 g, respectively).

Concerning morphometric traits, from week 2 to week 68, males had longer bodies, larger thoraxes, and longer tarsus than females. Likewise, Oguntunji and Ayorinde (2014) reported that the thoracic perimeter, body length, wing length, and whole thigh-drumstick total length of males (46.93 cm, 30.69 cm, 35.23 cm, and 17.18 cm, respectively) are higher than those of females (38.7 cm, 23.96 cm, 26.71 cm, and 14.55 cm, respectively).

Feed intake and feed conversion ratio

Individual feed intake and feed conversion ratio increased overall with age in this study. Body nutritional needs explain the increase in feed intake with age for birds' maintenance and growth. In the starting phase, animals consume little feed, with a higher average daily gain, which explains the low feed conversion ratio observed during this phase. When an animal becomes older, the average daily gain decreases, while feed intake increases with an increase in feed conversion ratio. The feed conversion ratio and growth rate averages recorded in this study are close to those obtained in Nigeria by Igwebuike and Anagor (2013). Besides, the increase in feed intake and feed conversion ratio with Muscovy ducks' age was also recorded in other studies. Makram et al. (2017) reported a feed intake of 1036.00 ±76.33 g for week 2 to week 4 and 2489.34 ± 77.06 g for week 8 to week 10 in Muscovy ducks. Concerning feed conversion ratio, they recorded 2.16 ± 0.10 and 2.98 ± 0.28, respectively, for these two periods. This same trend of feed intake and feed conversion ratio evolution with age was observed in other strains, such as Sudani and Pekin ducks (Makram et al., 2017; 2021).

Egg laying performance and egg characteristics of female duck

The Muscovy duck's age at the first egg was 6.17 months in the present study. This age confirms the observations of Retailleau and Blanchet (2003), who report that Muscovy ducks reach sexual maturity after 6 months of age. The average number of eggs laid per brood was 15.37 eggs, with an annual production of 47.54 eggs and an average weight of 63 g. These testify that Muscovy duck is a very good layer and prolific, compared to local chickens. This annual production is, however, below the results of Yakubu et al. (2011), who report that ducks can lay between 60 and 80 eggs each year with an average egg weight of around 72 g under better breeding conditions. The results of this study on laying performance confirm the results of Etuk et al. (2011), who observed that a duck is a good brooder and a good mother due to its reproductive performance. In Nigeria, Adeyeye (2009) recorded ducks' egg, shell, albumen, and yolk weights of 63.61g, 8.11g, 28.63g, and 24.08g, respectively. In addition, Banga-Mboko et al. (2007) study on the reproductive performance of Muscovy ducks in Congo revealed a brood size of 14.6

eggs and an average egg weight of 72 g. Widianingrum et al. (2020) also indicated close results.

CONCLUSION

The evaluation of the zootechnical performance of ducks in a controlled environment revealed that males had higher weights by aging and also had higher morphometric traits than females. The gap in sex performance increases with age. Regardless of sex, variables of live weight, body length, thoracic perimeter, tarsus length, and wingspan were significantly and positively correlated in all ducks. These correlations were more pronounced in males than in females. Individual feed intake and feed conversion ratio increased with age. The results of the present study can be considered as a reference for its potential improvement through subsequent studies.

DECLARATIONS

Authors' contributions

The experimental study was conceived and designed by Finagnon Josée Bernice Houessionon and Issaka Youssao Abdou Karim in consultation with Assouan Gabriel Bonou, Mahamadou Dahouda, and Guy Apollinaire Mensah. Tossou Jacques Dougnon and Issaka Youssao Abdou Karim supervised the experimental study, collection of data, and analysis. The manuscript was written and drafted by Finagnon Josée Bernice Houessionon. All authors read, reviewed, and approved the final manuscript for submission and publication.

Competing interests

The authors declare that they have no competing interests.

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Ethical considerations

Ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been checked by the authors.

Availability of data and materials

The datasets used and/or analyzed data during the current study are available from the corresponding author upon reasonable request.

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