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Influence of Overfeeding on Productive Performance Traits, Foie Gras Production, Blood Parameters, Internal Organs, Carcass Traits, and Mortality Rate in Two Breeds of Ducks

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Abstract**—**A total of 60 male mule ducks and 60 male Muscovy ducks were allotted into three groups (n = 20) to estimate the effects of overfeeding (two and four meals) versus *ad libitum* feeding on productive performance traits, foie gras production, internal organs, and blood parameters.

The results show that force-feeding four meals significantly increased ($P < 0.01$) body weight, weight gain, and gain percentage compared to force-feeding two meals. Both force-feeding regimes (two or four meals) induced significantly higher body weight, weight gain, gain percentage, and absolute carcass weight than *ad libitum* feeding; however, carcass percentage was significantly higher in *ad libitum* feeding. Mule ducks had significantly higher weight gain and weight gain percentages than Muscovy ducks.

Feed consumption per kilogram of foie gras and per kilogram weight gain was lower for the four-meal than for the two-meal forced feeding regime. Force-feeding four meals induced significantly higher liver weight and percentage (488.96 ± 25.78g, 7.82 ± 0.40%) than force-feeding two meals (381.98 ± 13.60g, 6.42 ± 0.21%). Moreover, feed conversion was significantly higher under forced feeding than under *ad libitum* feeding (77.65 ± 3.41g, 1.72 ± 0.05%; $P < 0.01$).

Forced feeding (two or four meals) increased all organ weights (intestine, proventriculus, heart, spleen, and pancreas) over *ad libitum* feeding weights, except for the gizzard; however intestinal and abdominal fat values were higher for four-meal forced feeding than for two-meal forced feeding.

Overfeeding did not change blood parameters significantly compared to *ad libitum* feeding; however, four-meal forced feeding improved the quality of foie gras since it significantly increased the percentage of grade A foie gras (62.5%) at the expense of grades B (33.33%) and C (4.17%) compared with the two-meal forced feeding.

The mortality percentage among Muscovy ducks during the forced feeding period was 22.5%, compared to 0% in mule ducks. Liver weight was highly significantly correlated with life weight after overfeeding and certain blood plasma traits.

Keywords**—**Foie gras, overfeeding, ducks, productive performance.

I. Introduction

OVERFEEDING certain waterfowl species induces a dramatic accumulation of fat in the liver (foie gras). This is because the liver is the major site for de novo lipogenesis in birds, as opposed to mammals, where it is the adipose tissue [13]. In such cases hepatic weight can increase more than 10-fold in less than 2 weeks and account for up to 10% of body weight [14]. However, overfeeding waterfowl also induces extensive fattening of peripheral tissues, such as adipose tissue and muscle [24].

Within the same species of waterfowl, the production of fatty liver is breed dependent. For example, the production of fatty liver is higher in overfed Landes geese than in overfed Poland geese [6]. Similarly, mule and Muscovy ducks exhibit a higher production of fatty liver than Pekin ducks [11]. Between Muscovy and mule ducks breeds, foie gras production is dependent on the feeding system used: Muscovy ducks produce a heavier fatty liver than Mule ducks when the birds are overfed according to their body weight, since the body weight of Muscovy ducks is higher than that of mule ducks [11]. However, when overfeeding is according to ingestion capacity, mule ducks record higher liver weights than Muscovy ducks, since their ingestion capacity is also higher [25] and [12].

The present study was designed to determine the implications of using four-time forced feeding in decreasing feed loss during forced feeding and improving foie gras production in two duck breeds, mule and Muscovy ducks.

II. Material and Methods

A. Ducks

A total of 90 male Muscovy ducks (*Cairina moschata*) and 90 male mule ducks (a sterile artificial hybrid resulting from crossing a Muscovy drake with a common female duck (*Anus plutyrhynchos*) hatched on the same day were grown under natural light and temperature conditions. They were housed collectively; however, the two genotypes were bred in separated pens in the Duck Research Unit, Department of Animal Husbandry and Animal Wealth Development, Faculty of Veterinary Medicine, Damanhour University.

III. Experimental Design

During the brooding period (0–3 weeks of age) the ducks had free access to a starting diet containing 19.1% crude protein and 3025.11 kcal. From 3 weeks to 11 weeks, they had free access to a growing diet containing 17.23% crude protein and 3154.42 kcal/kg according to [22]. From 6 weeks to 11

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weeks, the ducks' daily intake of the growing diet was reduced to 220 g/duck/day to avoid excessive fatness [15].

During the pre-overfeeding period (at 11 weeks of age) the feed restriction was progressively lifted to increase the digestive tract volume and to initiate metabolic adaptation to overfeeding. The daily feed intake spontaneously reached 380 g/duck/day in 8 days on a diet providing 2750 kcal and 155 g/kg protein.

At the end of the pre-overfeeding period (12 weeks of age) 60 ducks from each breed were chosen according to body weight and health conditions and divided equally into three groups: 1) an *ad libitum* feeding group, where birds were fed *ad libitum* a growing ration of 380 g/bird/day for 14 days; 2) a two-meal forced feeding group, where birds were fed two times per day with a 12-hour interval between the two meals; and 3) a four-meal forced feeding group, where the birds were force-fed four times per day, with the feed of each meal introduced in two occasions with an interval of 1.5 hours in between.

During the overfeeding period both forced feeding groups were crammed for 14 days with a carbohydrate-rich diet consisting of 98% ground corn, 1% salt, 0.5% vitamins and minerals, and 0.5% waterfowl fat or vegetable oil. The final mixture consisted of two parts feed and one part water.

On a dry basis, the amount of rations required by a mule duck was 10.7kg; however, a Muscovy duck required a ration of only 8.1kg, due to their different ingestion capacities [25]. During the first 8–10 days of the overfeeding period, the amount of feed was progressively increased each day until the maximum was reached. Water was available at all times.

The present work was carried out in agreement with the French national guidelines for the care and use of animals for research purposes.

IV. Estimation of Productive Performance

Body weight was estimated before the first meal and after the last meal of the overfeeding period. The ducks were deprived of feed for 12 hours and then each was weighed to the nearest gram. Weight gain was calculated by subtracting the initial weight from the final weight. Feed conversion was calculated in relation to liver weight (feed intake/liver weight) and weight gain (feed intake/weight gain), according to [17].

V. Estimation of Blood Plasma Traits

After the overfeeding period, the birds were fasted for 12 hours. Then 5-ml blood samples were collected in sterilized tubes from the wing vein of three birds per genotype. Plasma samples were separated by centrifugation at 3000 rpm for 10 minutes at 5^{o}C and then stored at -20^{o}C.

The plasma samples were analyzed for cholesterol levels according to [30], Alanine transferase (ALT) and aspartate transferase (AST) according to [23], glucose according to [28], high density lipoprotein cholesterol (HDL) according to [19], low density lipoprotein cholesterol (LDL) according to [29], urea according to Kaplan and [16], and triacylglycerol according to [10].

VI. Estimation of Internal Organs, Carcass Traits, and Abdominal Fat

The birds were weighed, hung from their legs, and manually slaughtered. After bleeding and scalding, the liver, internal organs (intestine, proventriculus, gizzard, pancreas, spleen, and heart), and abdominal fat (including gizzard fat) were excised and weighed and the carcass was weighed.

Foie gras quality was estimated according to [8] with grade A weighing 1.5–3 pounds, grade B weighing 0.75–1.5 pounds, and grade C weighing 0.66–0.75 pounds.

VII. Statistical Analysis

The data were analyzed by two-way analysis of variance with [26] using PROC GLM.

VIII. Results

A. Productive Performance Traits

Before the overfeeding period (at 12 weeks of age), the body weight of the Muscovy ducks was 12.11% heavier than that of the mule ducks (4563.67±111.53g vs. 4070.25±90.14g, respectively), similar findings were reported by [18] and [11]. However, after overfeeding, the difference in body weight between mule and Muscovy ducks was not significant (5761.58 ± 111.99g vs. 5676.53 ± 110.51g, respectively). These results may be related to the significantly higher weight gain achieved by mule ducks after the overfeeding period (1516.1 ± 128.23 g vs. 861.92 ± 94.24 g for mule and Muscovy ducks, respectively; $P < 0.01$). Similar results were obtained by [12] who found that although the body weights of the two duck breeds (mule and Muscovy ducks) were similar after forced feeding, the weight gain due to forced feeding was higher in mule ducks than in Muscovy ducks. Reference [1] also showed higher weight gains for mule ducks than for Muscovy ducks when overfeeding was at the maximum of the ducks' ingestion potential.

Feed consumption per kilogram weight gain did not differ significantly between mule ducks and Muscovy ducks (8.59 ± 1.26kg vs. 10.09 ± 1.22kg); however feed consumption per kilogram of foie gras was significantly higher in Moulord ***ducks*** than in Muscovy ducks (306.04 ± 136.33kg vs. 115.61 ± 50.89kg, respectively; $P < 0.05$).

The data presented in Table I show that a four-meal forced feeding regime significantly increased ($P < 0.01$) body weight and weight gain (6251.49 ± 84.29g and 2031.79 ± 83.79g, respectively) over two-meals forced feeding (5954.33 ± 64.27g and 1421.03 ± 113.68g, respectively) and *ad libitum* feeding (4506.75±107.06g and 411.05 ± 50.06g, respectively). These results may be related to the lower feed loss for the four-meal forced feeding regime than for the two-meal forced feeding regime. Moreover, the amount of feed in both forced feeding regimes was higher than in the *ad libitum* feeding regime. Similar results were obtained by [8] who concluded that forced feeding significantly increased body weight and weight gain, also similar results reported by [12] who reported that after 12.5 days of overfeeding, male mule ducks exhibited heavier body weight than control ducks (under *ad libitum* feeding).

Feed consumption per kilogram of foie gras and per kilogram weight gain was lower in the four-meal forced feeding regime than in the two-meal forced feeding regime (26.76± 1.88kg and 5.20 ± 0.18kg vs. 37.61 ± 2.77kg and 8.59 ± 1.03kg, respectively). These results can be attributed to the small amount of feed lost during the four-meal forced feeding regime. Moreover, both forced feeding regimes recorded significantly lower amounts of feed per kilogram liver or kilogram weight gain than the *ad libitum* feeding regime (1218.90 ±332.99kg and 15.24 ± 2.54kg, respectively). These results may be related to limitation of the birds' movements under forced feeding programs and the carbohydrate nature of feed, which allows the storage of fat in liver.

1. Internal Organs

Mule ducks had higher liver weights and liver percentage (362.38 ± 26.66g, 5.99 ± 0.83%, respectively) than Muscovy ducks (320.90 ± 23.76g, 5.50 ± 0.36%, respectively); however, the differences between values were not significant. Mule ducks also recorded higher gizzard (68.79 ± 1.75g, 1.23 ± 0.05%) and heart (38.69 ± 0.56g, 0.68 ± 0.01%) weight and percentage than Muscovy ducks (65.68±1.41g, 1.18±0.04% and 36.16 ± 1.05g, 0.64 ± 0.02% respectively). Moreover, pancreas weight and percentage were significantly higher ($P < 0.01$) in mule ducks (9.56 ± 0.17g, 0.17 ± 0.01%) than in Muscovy ducks (7.71 ± 0.30g, 0.14 ± 0.01%), as shown in Table II. On the other hand, Muscovy ducks had significantly higher intestinal weight than mule ducks (273.97 ± 12.38g and 4.77 ± 0.17% vs. 225.26 ± 11.39g and 3.81 ± 0.15%, respectively), as well as spleen weight and percentage (3.96 ± 0.29g and 0.07 ± 0.01% vs. 2.16 ± 0.10 g and 0.04 ± 0.01%, respectively) and proventriculus weight, percentage, and diameter (Tables II and III).

Four-meal forced feeding induced significantly higher liver weight and percentage (488.96 ± 25.78g, 7.82 ± 0.40%) than two-meal forced feeding (381.98 ± 13.60g, 6.42 ± 0.21%) and *ad libitum* feeding (77.65 ± 3.41g, 1.72 ± 0.05%), as shown in Table II. The superiority of four-meal forced feeding over two-meal forced feeding with the same amount of feed used can be attributed to the disappearance of feed waste with four-meal forced feeding, since dividing the amount of feed used per meal between two meals eases the introduction of the meal to the bird crop which was not completely filled and so no feed will return from it. This enables the bird to use each gram of feed in energy storage, resulting in higher liver weight. These results are consistent with those of [20] who found that liver weight was nearly 10-fold greater in overfed ducks, reaching approximately 8% of their body weight compared with only 1% in controls. Similarly [9] found that forced feeding increased absolute and proportional liver weight, carcass traits, and abdominal fat in male and female Pekin ducks over *ad libitum* feeding on a commercial diet.

Forced feeding regimes (two or four meals) increased the weights of all body organs (intestine, proventriculus, heart, spleen, and pancreas) over their weights under the *ad libitum* feeding regime (Tables II and III). These results may be due to the significant effects of the higher amount of feed introduced through the forced feeding regimes on organs directly affected by the feed amount (i.e., intestine and proventriculus), either as absolute weight or as a percentage of life weight. Pancreas, spleen, and heart percentages were lower under the forced feeding regimes than under the *ad libitum* feeding regime. These results may be attributed to the non-significant increase in their absolute weights due to forced feeding regimes with a significantly lower life weight under the *ad libitum* feeding regime, which decreased the value of the denominator to increase the percentage after division.

On the other hand gizzard weight and percentage significantly decreased under the forced feeding regimes compared to the *ad libitum* feeding regime (65.24 ± 1.11g, 1.09 ± 0.02%; 66.62±2.20g, 1.07 ± 0.04%; 74.74 ± 3.92g, 1.68 ± 0.1%, respectively; $P < 0.01$). These results may be related to the nature of the feed introduced during forced feeding (corn mash mixed with large amounts of water), which made the feed pass faster, thus decreasing the function of the gizzard (a muscular stomach that grinds the feed). However, under *ad libitum* feeding, the gizzard's function was not affected, since feed remained within it longer due to its lower water content.

The effects of breed on liver weight and percentage under different forced feeding regimes had the same trends (Table II). Moulord ducks under either the four-meal or the two-meals forced feeding regime had higher liver weights and percentages (515.31 ± 34.10g, 8.20 ± 0.54% and 398 ± 18.19g, 6.58 ± 0.29%, respectively) than Muscovy ducks (436.25 ± 31.22g, 7.07 ± 0.41% and 361.09 ± 20.07g, 6.21 ± 0.3%, respectively). On the other hand, Muscovy ducks under the *ad libitum* feeding regime recorded higher liver weight and percentage (90 ± 5.26g, 1.85 ± 0.09%) than mule ducks (69.41 ± 2.51g, 1.63 ± 0.05%).

We can conclude from these data that the incidence of hepatomegaly in mule ducks increased 7.42-fold as absolute weight and fivefold as a percentage of life weight under four-meal forced feeding compared to *ad libitum* feeding, and 5.73-fold and four fold, respectively, under the two-meal forced feeding regime. In Muscovy ducks, these values under the same treatments increased 4.85-fold and 3.82-fold versus fourfold and 3.36-fold, respectively, under the four-meal and two-meal forced feeding regimes, respectively. As stated by [4]. Similar results were obtained when comparing overfeeding at maximum ingestion potential with *ad libitum* feeding in four duck genotypes (Muscovy, Pekin, and their crossbreed mule and hinny ducks). The authors found that overfeeding increased liver weight 8.1-fold in mule and Hinny ducks, 6.1-fold in Muscovy ducks, and 5.7-fold in Pekin ducks.

2. Carcass Traits and Abdominal Fat

Muscovy ducks had significantly higher carcass weight and percentage than mule ducks after the overfeeding period (3687.18 ± 67.69g and 65.10 ± 0.52% vs. 3597.84 ± 67.22g and 62.45 ± 0.42%, respectively). Moreover, force-feeding two or four meals induced significantly higher absolute carcass weight than *ad libitum* feeding. On the contrary, carcass percentage was significantly higher for *ad libitum* feeding (66.24 ± 0.95%) than for forced feeding (63.11 ± 0.35% and 62.19 ± 0.67% for two meals and four meals, respectively; $P < 0.01$). However, carcass weight and percentage did not differ significantly between the different forced feeding regimes. These results may be attributed to the higher weight of all internal organs in the force-fed groups than for the *ad libitum* fed groups, which decreased carcass percentage.

Muscovy ducks had significantly higher abdominal fat weight and percentage than mule ducks (137.18 ± 8.74g, 2.35 ± 0.13% vs.124.40 ± 8.04g, 2.04 ± 0.13%, respectively; $P < 0.01$). Moreover four-meal forced feeding produced significantly heavier abdominal fat weight (162.38 ± 6.50g) than two-meal forced feeding (151.58 ± 4.13g), both of which produced significantly heavier abdominal fat weight than *ad libitum* feeding (31.70 ± 6.76g; $P < 0.01$). In addition, the abdominal fat percentage under both forced feeding regimes was significantly higher than under the *ad libitum* feeding regime (2.59 ± 0.09%, 2.54 ± 0.06%, and 0.68 ± 0.14% for four and two meals force fed and *ad libitum* feeding, respectively; $P < 0.01$). However, the difference in fat percentage under the different forced feeding regimes was not significant (Table IV).

Muscovy ducks had higher abdominal fat weight and percentage than mule ducks under the *ad libitum* feeding regime and the four-meal forced feeding regime; however, differences between the two breeds under the two-meal forced feeding regime were not significant for either abdominal fat absolute weight or percentage. Similar results were reported by [7] who found that the difference between mule and Muscovy ducks in abdominal fat percentage after overfeeding was not significant, with an average of 2.5% body weight. Reference [3] showed that the increase in the amount of abdominal fat from forced feeding was greater in Pekin ducks than in Hinny and mule ducks, with Muscovy ducks exhibiting the lowest increase.

3. Plasma Biochemical Traits

The data presented in Table V show that Muscovy ducks had significantly ($P < 0.01$) higher glucose levels than mule ducks (191.75 ± 26.46 vs. 54.26 ± 10.86, respectively). On the other hand, other plasma parameters and hepatic enzymes were higher in Moulord ducks than in Muscovy ducks. However, the differences between the values for Moulord and Muscovy ducks were significant only for cholesterol (128.34 ± 6.19 vs. 116.21 ± 7.01, respectively) and AST (93.40 ± 10.17 vs. 58.81 ± 4.36, respectively).

Under *ad libitum* feeding, there were no significant differences in blood plasma parameters between Muscovy and mule ducks (Table V), except for HDL, which was significantly higher ($P < 0.01$) in mule ducks than in Muscovy ducks (64.92 ± 7.65 vs. 34.47 ± 3.21, respectively). The blood glucose level of Mule ducks decreased under the forced feeding regime compared to *ad libitum* feeding and the opposite was true in Muscovy ducks. These results suggest that mule ducks are better at using glucose, whatever the feeding level, than Muscovy ducks. Similar results were concluded by [7] who found that fasting plasma glucose and triacylglycerol levels before the first overfeeding meal were similar for both Muscovy and mule ducks; however, on the 10th day of the overfeeding period, Muscovy ducks had increased glycemia compared to the first day, whereas it was decreased in the mule ducks.

Mule ducks recorded significantly higher cholesterol and ALT values under four- meal forced feeding and significantly higher LDL values under two-meal forced feeding than Muscovy ducks (Table V). These results are consistent with those of [3] who found that after forced feeding Muscovy ducks had lower levels of plasma phospholipids and total cholesterol than mule ducks.

Both mule and Muscovy ducks' cholesterol and ALT levels were significantly higher under forced feeding than under *ad libitum* feeding; however, the mule ducks' HDL levels were significantly higher under *ad libitum* feeding than under the two-meal forced feeding regime (Table V).

4. Foie Gras Quality (Foie Gras Grade)

Foie gras quality can be evaluated by grade estimation according to weight. The different foie gras grades were estimated for the two duck breeds (Table VI) and the results show that the percentage of grades A, B, and C in mule ducks (48.84%, 32.56%, and 18.6%, respectively) are not statistically different from those in Muscovy ducks (39.13%, 47.83%, and 13.04%, respectively). Similar results were found by [21] who determined that 41.2% of 10-week-old force-fed Rhenish geese were producing class 1/class 2 foie gras, as well as [2] who found that 58.5% of 9-week-old Hugavis Combi x white Landes geese cram-fed for 19 days had class I ± II livers.

Four-meal forced feeding (Table VII) significantly improved foie gras quality, increasing the percentage of grade A (62.50%) at the expense of grade B (33.33%) and C (4.17%), over that obtained with two-meal forced feeding (35.71%, 40.48%, and 23.81% for grades A, B, and C, respectively). In mule ducks (Table VIII) the percentage of grade A foie gras under four-meal forced feeding was significantly higher than under two-meal forced feeding (68.75% vs. 37.04%, respectively) and the opposite was true for grades B and grade C; however, in Muscovy ducks (Table IX), the differences between foie gras grades under different forced feeding regimes were not significant.

Mortality Percentage

The mortality percentage during the forced feeding period was 22.5% in Muscovy ducks, with nine of 40 ducks dying during forced feeding; however, in mule ducks the percentage was 0%. This result disagreed with those of [5] who stated that average mortality reached 18.9% in mule ducks force fed at 10 weeks of age for 15–20 days. However, our results agreed with those of [27] where the mortality rate of 77,519 ducks in 16 production units in Belgium was obtained by veterinary inspectors. The overall mortality observed was 2.75%, varying from 0% to 15% between the farm and batches.

IX. Conclusion

The data suggest that in foie gras production a four-meal forced feeding regime is preferable to the ordinary two-meal forced feeding regime and mule ducks are better than Muscovy ducks.

TABLE I
LEAST SQUARES MEANS AND STANDARD ERRORS OF THE EFFECT OF BREED AND FEEDING REGIME AND THEIR INTERACTIONS ON THE BODY WEIGHT (G), WEIGHT GAIN (G), FEED CONSUMPTION (KG) PER LIVER (KG), AND FEED CONSUMPTION (KG) PER WEIGHT GAIN (KG) IN MOULORD AND MUSCOVY DUCKS

Item		BW 12 WS	BW 14 WS	Weight gain	Feed/ liver	Feed /weight
Breed						
Moulord		4070.25±90.14^{b}	5761.58±111.99	1516.1±128.23^{a}	306.04±136.33^{a}	8.59±1.26
Muscovy		4563.67±111.53^{a}	5676.53±110.51	861.92±94.24^{b}	115.61±50.89^{b}	10.09±1.22
Feeding regime						
Ad libitum		4103.33±58.76	4506.75±107.06^{c}	411.05±50.06^{c}	1218.90±332.99^{a}	15.24±2.54^{a}
2 forced feeding		4369.41±150.35	5954.33±64.27^{b}	1421.03±113.68^{b}	37.61±2.77^{b}	8.59±1.03^{b}
4 forced feeding		4294.44±116.12	6251.49±84.29^{a}	2031.79±83.79^{a}	26.76±1.88^{b}	5.20 ±0.18^{c}
Breed*Feeding regime						
Moulord	*Ad libitum*	3998.75±52.85	4272.08±77.27^{c}	385.45±75.50^{d}	1860.63±512.75^{a}	18.89±4.44^{a}
	2 forced feeding	4051±174.51	6080.52±64.63^{a}	1808.16±129.37^{b}	39.91±3.64^{c}	6.30±0.33^{cd}
	4 forced feeding	4150±91.5	6300.63±82.46^{a}	2142.27±75.01^{a}	27.74±2.42^{c}	5.07±0.21^{d}
Muscovy	*Ad libitum*	4187±82.56	4858.75±184.39^{b}	446.25±61.69^{d}	485.50±189.15^{b}	11.06±0.80^{bc}
	2 forced feeding	4824.29±150.06	5795.22±113.50^{ab}	930.67±105.11^{c}	34.63±4.23^{c}	11.50±2.11^{b}
	4 forced feeding	4583.33±239.47	6153.13±197.04^{a}	1626.67±73.11^{b}	24.79±2.96^{c}	5.46±0.32^{cd}

Means within the same column with different superscripts are significantly different.
BW 12 WS = body weight at 12 weeks of age BW 14 WS = body weight at 14 weeks of age

TABLE II
LEAST SQUARES MEANS AND THEIR STANDARD ERRORS OF THE EFFECT OF BREED AND FEEDING REGIME AND THEIR INTERACTIONS ON INTERNAL ORGAN WEIGHTS (G) AND PERCENTAGES PER LIFE WEIGHT IN MOULORD AND MUSCOVY DUCKS

Item		Liver		Intestine		Gizzard		Pancreas	
		Weight	%	Weight	%	Weight	%	Weight	%
Breed									
Moulord		362.38±26.66	5.99±0.38	225.26±11.39^{b}	3.81±0.15^{b}	68.79±1.75	1.23±0.05^{a}	9.56±0.17^{a}	0.17±0.01^{a}
Muscovy		320.90±23.67	5.5±0.36	273.97±12.38^{a}	4.77±0.17^{a}	65.68±1.41	1.18±0.04^{b}	7.71±0.30^{b}	0.14±0.01^{b}
Feeding regime									
Ad libitum		77.65±3.41^{c}	1.72±0.05^{c}	121.25±10.84^{c}	2.64±0.18^{b}	74.74±3.92^{a}	1.68±0.10^{a}	8.88±0.42	0.20±0.01^{a}
2 forced feeding		381.98±13.60^{b}	6.42±0.21^{b}	270.57±7.19^{b}	4.58±0.12^{a}	65.24±1.11^{b}	1.09±0.02^{b}	8.60±0.26	0.14±0.01^{b}
4 forced feeding		488.96±25.78^{a}	7.82±0.40^{a}	291.04±13.82^{a}	4.67±0.23^{a}	66.62±2.20^{b}	1.07±0.04^{b}	9.20±0.29	0.15±0.01^{b}
Breed* Feeding regime									
Moulord	*Ad libitum*	69.41±2.51	1.63±0.05	90.83±4.43^{c}	2.13±0.10^{e}	77.07±5.93	1.82±0.15^{a}	9.66±0.47	0.22±0.01^{a}
	2 forced feeding	398.00±18.19	6.58±0.29	260.17±11.25^{ab}	4.32±0.16^{c}	65.78±1.55	1.07±0.02^{c}	9.45±0.28	0.16±0.01^{b}
	4 forced feeding	515.31±34.10	8.20±0.54	260.63±13.35^{ab}	4.13±0.20^{c}	68.22±3.05	1.08±0.05^{c}	9.69±0.26	0.15±0.01^{bc}
Muscovy	*Ad libitum*	90.00±5.26	1.85±0.09	166.88±14.27^{b}	3.41±0.23^{d}	71.25±4.30	1.46±0.06^{b}	7.80±0.60	0.16±0.01^{b}
	2 forced feeding	361.09±20.07	6.21±0.3	284.13±10.43^{ab}	4.90±0.15^{b}	64.53±1.59	1.12±0.04^{c}	7.50±0.36	0.13±0.01^{d}
	4 forced feeding	436.25±31.22	7.07±0.41	351.88±18.00^{a}	5.75±0.32^{a}	63.43±2.40	1.04±0.05^{c}	8.23±0.58	0.13±0.01^{cd}

Means within the same column with different superscripts are significantly different.

TABLE III
LEAST SQUARES MEANS AND THEIR STANDARD ERRORS OF THE EFFECT OF BREED AND FEEDING REGIME AND THEIR INTERACTIONS ON INTERNAL ORGAN WEIGHTS (G) AND PERCENTAGES PER LIFE WEIGHT IN MOULORD AND MUSCOVY DUCKS

Item	Heart		Spleen		Proventriculus		
	Weight	%	Weight	%	Weight	%	Diameter
Breed							
Moulord	38.69±0.56	0.68±0.01^{a}	2.16±0.10^{b}	0.04±0.01^{b}	13.89±0.57^{b}	0.24±0.01^{b}	6.58±0.23^{b}
Muscovy	36.16±1.05	0.64±0.02^{b}	3.96±0.29^{a}	0.07±0.01^{a}	26.15±1.63^{a}	0.47±0.03^{a}	7.72±0.41^{a}
Feeding regime							
Ad libitum	34.90±1.38	0.78±0.03^{a}	2.71±0.34	0.06±0.01	14.67±2.51^{b}	0.32±0.05	5.57±0.43^{b}
2 forced feeding	38.41±0.71	0.64±0.01^{b}	3.06±0.24	0.05±0.01	19.82±0.15^{a}	0.34±0.02	7.30±0.24^{a}
4 forced feeding	38.38±1.06	0.61±0.01^{b}	2.66±0.26	0.04±0.01	19.59±2.14^{a}	0.32±0.03	7.62±0.45^{a}
Breed* Feeding regime							

	Ad libitum	34.90±0.88	0.82±0.02	1.64±0.16	0.04±0.01	8.51.±0.53d	0.2±0.01	4.92±0.23
Moulord	2 forced feeding	40.04±0.74	0.66±0.01	2.30±0.14	0.04±0.01	15.48±0.76^{c}	0.25±0.01	7.00±0.27
	4 forced feeding	39.01±1.17	0.62±0.02	2.19±0.16	0.03±0.01	14.28±0.65^{c}	0.23±0.01	6.86±0.47
	Ad libitum	34.90±3.32	0.71±0.05	3.91±0.37	0.08±0.01	22.38±4.29^{b}	0.46±0.09	6.39±0.87
Muscovy	2 forced feeding	36.27±1.20	0.62±0.02	4.06±0.44	0.07±0.01	25.47±1.80^{ab}	0.45±0.04	7.69±0.42
	4 forced feeding	37.10±2.23	0.6±0.03	3.67±0.55	0.06±0.01	33.78±3.45^{a}	0.55±0.05	9.63±0.48

Means within the same column with different superscripts are significantly different.

TABLE IV
LEAST SQUARES MEANS AND THEIR STANDARD ERRORS OF THE EFFECT OF BREED AND FEEDING REGIME AND THEIR INTERACTIONS ON CARCASS WEIGHT (G), DRESSING PERCENTAGE, AND ABDOMINAL FAT WEIGHT (G) AND PERCENTAGE OF LIFE WEIGHT IN MOULORD AND MUSCOVY DUCKS

Item		Carcass		Abdominal fat	
		Weight	%	Weight	%
		Breed			
Moulord		3597.84±67.22^{b}	62.45±0.42^{b}	124.40±8.04^{b}	2.04±0.13^{b}
Muscovy		3687.18±67.69^{a}	65.10±0.52^{a}	137.18±8.74^{a}	2.35±0.13^{a}
		Feeding regime			
Ad libitum		2991.00±96.15^{b}	66.24±0.95^{a}	31.70±6.76^{c}	0.68±0.14^{b}
2 forced feeding		3761.42±43.68^{a}	63.11±0.35^{b}	151.58±4.13^{b}	2.54±0.06^{a}
4 forced feeding		3887.50±66.91^{a}	62.19±0.67^{b}	162.38±6.50^{a}	2.59±0.09^{a}
		Breed*Feeding regime			
	Ad libitum	2727.08±51.28^{c}	63.92±1.02^{b}	14.83±3.30d	0.36±0.08^{d}
Moulord	2 forced feeding	3805.33±44.15^{a}	62.49±0.47^{bc}	151.67±4.03^{b}	2.50±0.06^{b}
	4 forced feeding	3861.88±76.06^{a}	61.29±0.90^{c}	155.44±8.30^{b}	2.46±0.12^{b}
	Ad libitum	3386.88±138.65^{b}	69.71±0.92^{a}	57.00±11.50^{c}	1.16±0.24^{c}
Muscovy	2 forced feeding	3704.13±82.32^{ab}	63.89±0.51^{b}	151.48±8.06^{b}	2.59±0.11^{ab}
	4 forced feeding	3938.75±137.02^{a}	63.99±0.55^{b}	176.25±8.95^{a}	2.86±0.10^{a}

Means within the same column with different superscripts are significantly different

TABLE V
LEAST SQUARES MEANS AND THEIR STANDARD ERRORS OF THE EFFECT OF BREED AND FEEDING REGIME AND THEIR INTERACTIONS ON VARIOUS BLOOD PLASMA TRAITS IN MOULORD AND MUSCOVY DUCKS

Item		Glucose	Triacylglycerol	Cholesterol	HDL	LDL	UREA	ALT	AST
					Breed				
Moulord		54.26±10.68^{b}	320.71±37.47	128.34±6.19^{a}	39.15±5.52	25.05±2.01	12.22±1.27	64.20±3.93	93.40±10.17^{a}
Muscovy		191.75±26.46^{a}	313.75±34.14	116.21±7.01^{b}	32.36±4.94	21.1±1.7	12.03±1.85	58.00±3.63	58.81±4.36^{b}
					Feeding regime				
Ad libitum		107.36±16.54	83.08±2.46	84.66±8.82	49.7±7.76	18.35±1.19	6.06±0.28	42.83±1.96	44.00±3.29
2 forced feeding		134.91±41.6	395.98±25.42	134.90±4.81	32.52±5.67	23.18±2.14	15.80±2.04	66.77±3.32	83.15±7.88
4 forced feeding		124.53±25.15	348.71±19.94	126.90±5.66	32.00±5.73	25.17±2.34	11.16±0.87	63.83±4.24	83.08±11.72
					Breed*Feeding regime				
	Ad libitum	118.09±32.97	84.56±4.29	101.90±8.96^{b}	64.92±7.65^{a}	20.07±1.8^{ab}	6.37±0.44	41.67±0.67^{bc}	46.67±3.18
Moulord	2 forced feeding	42.19±6.62	400.81±35.79	131.91±8.76^{ac}	23.29±5.06^{b}	28.46±3.35^{a}	14.53±2.28	64.17±4.04^{a}	98.50±13.36
	4 forced feeding	34.42±4.68	358.69±37.36	137.99±9.17^{a}	42.12±7.56^{ab}	24.14±3.40^{ab}	12.83±1.25	75.50±3.95^{a}	111.67±15.9
	Ad libitum	96.62±12.85	81.60±3.10	67.41±3.34^{b}	34.47±3.21^{b}	16.62±0.93^{b}	5.74±0.30	44.00±4.16^{bc}	41.33±6.06
Muscovy	2 forced feeding	227.63±64.27	391.83±38.46	137.46±5.36^{a}	40.43±8.86^{ab}	18.66±1.29^{b}	16.89±3.37	69.00±5.24^{a}	70.00±6.38
	4 forced feeding	201.77±13.4	338.73±17.7	115.82±2.75^{bc}	21.88±6.79^{b}	26.20±3.48^{ab}	9.50±0.80	52.17±3.03^{bc}	54.50±4.94

Glucose, triacylglycerol, cholesterol, and urea measured in mg/dl.
HDL = High Density Lipoprotein (mg/dl), LDL = Low Density Lipoprotein (mg/dl), ALT = Alanine Transferase (u/ml) and AST = Aspartate Transferase (u/ml)

TABLE VI
EFFECT OF BREED ON THE PERCENTAGES OF DIFFERENT FOIE GRAS GRADES

Breed	Grade A %	Grade B%	Grade C%
Mule ducks	48.84	32.56	18.6
Muscovy ducks	39.13	47.83	13.04

Percentages within the same column with different superscripts are significantly different; χ2= 1.5109.

TABLE VII
EFFECT OF OVERFEEDING ON THE PERCENTAGES OF DIFFERENT FOIE GRAS GRADES

Feeding regime	Grade A%	Grade B%	Grade C%
2-meal forced feeding	35.71^{b}	40.48^{a}	23.81^{a}
4-meal forced feeding	62.50^{a}	33.33^{b}	4.17^{b}

Percentages within the same column with different superscripts are significantly different; χ^2= 6.1521.

TABLE VIII
EFFECT OF OVERFEEDING ON THE PERCENTAGES OF DIFFERENT FOIE GRAS GRADES IN MULE DUCKS

	Feeding regime	Grade A%	Grade B%	Grade C%
Mule ducks	2 meal feeding	37.04[b]	33.33[a]	29.63[a]
	4 meal feeding	68.75[a]	31.25[b]	0[b]

Percentages within the same column carry different superscripts are significantly different; $\chi 2$= 6.82.

TABLE IX
EFFECT OF OVERFEEDING ON THE PERCENTAGES OF DIFFERENT FOIE GRAS GRADES IN MUSCOVY DUCKS

	Feeding regime	Grade A%	Grade B%	Grade C%
Muscovy ducks	2 meal feeding	33.33	53.33	13.33
	4 meal feeding	50	37.5	12.5

Percentages within the same column with different superscripts are significantly different; $\chi 2$= 0.6466

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