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RESEARCH ARTICLE

Productive Traits, Biochemical Parameters, Meat Quality, and the Gene Expression in Different Duck Breeds

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Abstract

This research was performed to evaluate"productive traits, biochemical parameters, meat quality and the expression of related genes in different duck breeds". This experiment was conducted on 80 ducks (20Pekin, 20 Star 53, 20 Muscovy, and 20 Mulard). Each breed was reared under the same ecological, managerial, and sanitary conditionsfrom one day old until the end of the experiment (12th week of the age). The growth performance, biochemical characteristics, physicochemicalparameters of meat, and gene expression ofGrowth hormone(GH),Insulin like growth factor 1(IGF1),and calpain genes were analyzed and estimated. The findings showed that Mulard ducks had significantly greater ($p<0.05$) body weight (4234 g) followed byMuscovy (4029 g), Star 53 (3659 g), and Pekin (2961 g) althoughthe feed conversion ratio (FCR) of Pekin ducks was higher ($p<0.05$) than others. Mulard hadthe longest shank, body length, keel length, and body circumference (8.28, 78.50, 20.21, and 38.60 cm, respectively) at the end of the experiment. Pekin ducks recorded the highest values of total cholesterol (TC), superoxide dismutase (SOD), and glutathione peroxidase (GPX). While, Mulard recorded the highest values of Glucose, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and malondialdehyde (MDA). The lowest shear force value for breast and thigh muscles was observed in Muscovy ducks. GH, IGF-1 expression was higher in Mulard than other breeds. While, Calpain gene expression was higher ($p<0.05$) in Muscovy than in Mulard, Star 53, and Pekin. From the obtained results, it could be concluded that the observed highly productive traits in Mulard ducks might be attributed to the difference in gene expression related to growth.However, thegood meat quality in Muscovy ducks wasowing to the high expression ofthe Calpaingene.

Keywords:

duck breeds; biochemical blood parameters; body measurements; Meat quality; Gene expression.

Introduction

The progress of duck production had expanded over the past 20 years, where about 1.15 billion ducks were kept around the world in 2017 [1]. Egypt has recently focused on increasing meat production, particularly ducks, which are believed to be the easiest domestic bird to raise [2,3].Pekin, Aylesbury, Rouen, and Muscovy ducks are the most popular breeds used for meat production [4,5].Pekin ducks have white plumage and are distinguished by their tasty meat [6].Due to their quick growth and disease resistance, white Pekin ducks are utilized to improve strains [7]. Muscovy ducks are very popular because of their various environmental adaptations, distinctive taste, high breast meat, and low-calorie level [8]. The Mulard (a Muscovy and Pekin duck hybrid) is raised for its meat and fattened liver[9].

The weighing of animals is the simplest methodfor evaluating an animal's mass. But in certain circumstances, a scale could not be accessible. Asubstitute is to measure a body portion and correlate the measurement to body weight (BW). Shank length is the body portion that is usually evaluated in poultry to correlate with BW. There has been research showing a direct correlation between BW and shank length [10].Body size and body measurement have been used as parameters for selection by local sellers and research [11]. Comparing phenotypes based on morphological characteristics is a useful way to illustrate the genetic diversity among populations. The selection of appropriate breeding objectives and plans depends on the genetic diversity of the duck populations[12].

The term "biochemical" describes the study of chemical processes that occur within and correlate with living organisms. Hematological and biochemical tests have not frequently been effective for the diagnosis of avian species, but these tests may be a suitable diagnosis mechanism for assessing health status, observing sick ducks' responses to treatment plans, and providing a prognosis for some duck diseases [13].

One of the most significant economic characteristics in the domestic animal industry is body growth which is controlled bymany factors including endocrine factors. Consequently, many endocrinological investigations have been carried out to enhance body growth in numerous species[14,15]. More specifically, growth factors, such as *IGF-1*have been shown to stimulate body growth in mammals [16].Many of the anabolic activities of *GH* are regulated by IGF-1 [17]. The growth of body tissues is stimulated by *IGF-I* levels, which are influenced by *GH* production [18]. *GH*controlsthe growth of various tissuesafter birth, including skeletal muscles [19].

The maintenance and improvement of human health and well-being depend on food quality. Previously, it had been statedthat duck meat is abundant in nutrients and low in cholesterol. Researchers have become more interested in duck meat quality and related food quality concerns[20,21].Some of the parameters that influence meat quality are tenderness, water-holding capacity, color, nutritional content, and safety. The value of these traits'changes depending on the product type and the consumer characteristic [22].

One of the most essential factors influencingoverall meat quality is tenderness. Meat tenderness varies according to breed, nutrition, husbandry, and slaughter methods. The calpain system (Ca2 + activated neutral proteinases) is probably one of the major components related to meat tenderness, and itsinfluences on postmortem tenderization have been well reported. Ca2 + can activate calpain after slaughtering the animal and causes the breakdown of postmortem myofibrillar protein as well as tenderness improvement [23,24].There were few studies on the *Calpain* gene in ducks, so the first aim of this research is to evaluate the level of the *Calpain* gene in breast muscle among different duck breeds and its association with meat tenderness. The second aim is to assess the level of GH and *IGF1* expression and their relation with productive traits.

Materials and Methods

Birds and Management

This research was approved by the Animal Care and Welfare Committee of ZagazigUniversity, Egypt (ZU-IACUC/2/F/149/2022). A total of 80 ducks (20 Pekin, 20 Star 53, 20 Muscovy, and 20 Mulard ducks) were obtained from EL-Wafaa Farm Company in Giza and rearedunder the same ecological, managerial, and sanitary conditions from one day old until the end of the experiment (12th week of age). They were kept in pens with similar floor area (5 ducks/ m^2) covered with 5 cm thickness of wood shaving. The environmental temperature was provided at 34°C for the first three days, then declined by about 2°C per week till it reached 25°C, and the light was continuous. The feed was supplied ad libitumwith the starter ration 22٪ (cp) was offeredfrom 1st to 4th week of age. While, from 5th to 12th week of age, the grower/finisher ration 18٪ (cp) offered byNRC [25].

Measurements and observations

Productive traits

Growth performance traits included initial BW, final BW, average feed intake (AFI), and feed conversion ratio (FCR). The initial BW of all ducks was recorded onthe first day of age. At 12th week of age, we evaluated the final BW of all ducks after 12h fast. AFI and FCR were estimated on replicate basis.Feed consumption for the total period divided by total body weight gain to estimate the feedconversion ratio (FCR).Body measurements were measured bi-weekly to determine shank length, keel length,breast circumference, and body lengthaccording to Makram *et al*.[26]as the following:

Shank Length: was evaluated on live duck by determining the length of the tibiotarsus from the top of the hock joint to the foot pad with a digital caliper (cm).

Body Length: Starting from the beak to the end of the bird's foot (cm).

Keel Length: was determined for each duck individually by a digital caliper (cm).

Breast circumference:was measured under the wings at the edge of the sternum.

Serum biochemical parameters

Blood samples were taken during slaughtering at the 12th week of agefrom the jugular vein under aseptic circumstances. Samples were collected in test tubes without EDTAand then centrifuged at 2500 rpm for 12 min for serum collection. Serum samples were kept at -20°C until used for serum biochemical characterization analysis. Serum glucose, albumin, uric acid, total protein, triacylglycerol, total cholesterol, high-density lipoprotein and low-density lipoprotein were determined in a digital spectrophotometer (Biomate 5, Thermo Electron Corporation, Rochester, NY, USA) by using commercial kits (Nanjing Jiancheng Institute of Bioengineering, Nanjing, China). Serum malondialdehyde, glutathione peroxidase and superoxide dismutase activities were estimated using ELISA Kit of QuantiChrom™ (Hayward, CA, SA), BioAssay Systems (Hayward, CA, USA) and Cayman Chemical Company (Hayward, CA, USA); respectively.

Physico-chemical properties of meat

Breast and thigh muscleswere stored at 4°C for 24h post-mortumto assess pH, color, water holding capacity, drip loss, cooking loss, shear force, and thio-barbituric acid reducingsubstances. Ultimate pH (pHu)was measured after 24 h of chillingandevaluated by operating an electrical pH meter (Bye model 6020, USA) that was adjusted daily with standard pH buffers of 4.0 and 7.0 at 25°C[27].The surface color as CIE L*-(lightness), a*-(redness), and b*-(yellowness) values werecalculated using a Hunter Lab Color Meter (D25-INC4750- Hunter Associate Lab, Reston, Virginia, USA) [28].

Water holding capacity was estimated as the ratio (%) of the volume of released water to the tested intact duck meat [29].Drip loss (%) was estimated according to the difference between the first weight of the samples measured at the facility and the second weight of them calculated af1-day day post-mortem during chilling storage at 4°C [30].Cooking loss was determined as theproportionof weight loss to a constant weight after cooking (W2)and the initial weight (W1)[31].

$$\text{Cooking loss\%} = \frac{\text{W1} - \text{W2}}{\text{W1}} \times 100$$

The shear force was measured with a blade (68mm wide × 72 mm long × 3mm thick) by using instron device 1195 (England). The blade speed 10 mm/min was used to perform shear force analysis and the pickup force of the calculating head was 50 Kg with the muscle fibers parallel to the direction of the blade. The findings were given in kilograms of shear force[32].The quantities of thio-barbituric acid reducing substances (TBARS)were represented as milligrams of malondialdehyde per kilogram of meat [33].

Determination of the relative expression of growth-related genes (Growth hormone(GH), Insulin like growth factor 1(IGF-1)), and Calpain gene.

For the expression of *IGF-1*, *GH*, and Calpain genes, samples of breast muscle were taken and put in sterile tubes (RNase-free), which were then directly submerged in liquid nitrogen prior to storage at -80˚C until use. RNA extraction from tissue samples was utilized using the QIAamp RNeasy Mini kit (Qiagen, Germany, GmbH). Preparation of tissue samples and extraction of RNA was prepared following kit instructions. 25- µl reaction containing 12.5 µl of the TransScript Green One-Step qRT-PCR SuperMix®, 1 µl of RT Enzyme Mix (20X), 0.5 µl of each primer (forward and reverse) of 20 pmol concentration, 0.5 µl reference dye, 5 µl of water, and 5 µl of RNA template. The reaction was performed in a step one real time PCR machine. Primers [34, 35] used were supplied from Metabion (Germany)and are listedin Table (1). Amplification curves and CT values were established by step one software. To evaluate the variation of gene expression on the RNA of the various samples, the CT of each sample was compared with that of the control group (Pekin duck) according to the "ΔΔCT” method declared by Yuan *et al*. [36]utilizing the following ratio: ($2^{-\Delta\Delta CT}$).

Table 1.Primer sequences and cycling conditions for SYBR green real-time PCR.

Target gene	Primers sequences (5′→3′)	Reverse transcription	Primary denaturation	Amplification (40 cycles) denaturation	Annealing	Extension	Reference
B- actin	F:5′-GTGGATCAGCAAGCAGGAGT-3′ R:5′-TTTGTCACAAGGGTGTGGGT-3′	50˚C 30 min.	94˚C 15 min.	94˚C 15 sec.	55˚C 30 sec.	72˚C 30 sec.	[34]
Calpain	F:5′-AAGCGACATTGGCGAACT-3′ R:5′CCAGCCCACAAGACATCC-3′-						[35]
[1]*IGF-1*	F:5′-GCCATCTGCAGGATACTTTGC-3′ R:5′-CTGGGAGAATGCCCATTGGT-3′						[34]
[2]*GH*	F:5′-TTT GCC AAC GCT GTGC-3′ R:5′-CTG GGC ATC ATC CTT CC-3′						[8]

The [1]*IGF-1* primer (insulin growth factor-1), [2]*GH* primer(growth hormone).

Statistical analysis

Results were described as mean ± SEM (standard error of mean). In order to evaluate the effect of the 4 breeds, one-way analysis of variance (ANOVA) was applied. Duncan multiple tests as post hoc test were utilized to determine the difference between means. The value of $P < 0.05$ was employed to demonstrate statistical significance. All analyses and charts were drawn with Statistical Package for Social Sciences version 24.0 (SPSS, IBM Corp., Armonk, NY) and Graph Pad Prism 8.0.2 (GraphPad Software, Inc).

Results

There was a significant difference in growth performance among different duck breeds.The Mulard breed exhibited the highest final BW (4234 g) followed by the Muscovy (4029 g), Star 53 (3659 g) and Pekin (2961 g).Furthermore, AFI was significantly reduced in Muscovy breed (14316 kg)compared to Star 53 (16786 kg).The highest feed conversion ratio was recorded for Pekin ducks followed by Star 53. While Muscovy and Mulard exposed no significant change in feed conversion ratio as shown in (Figure 1).

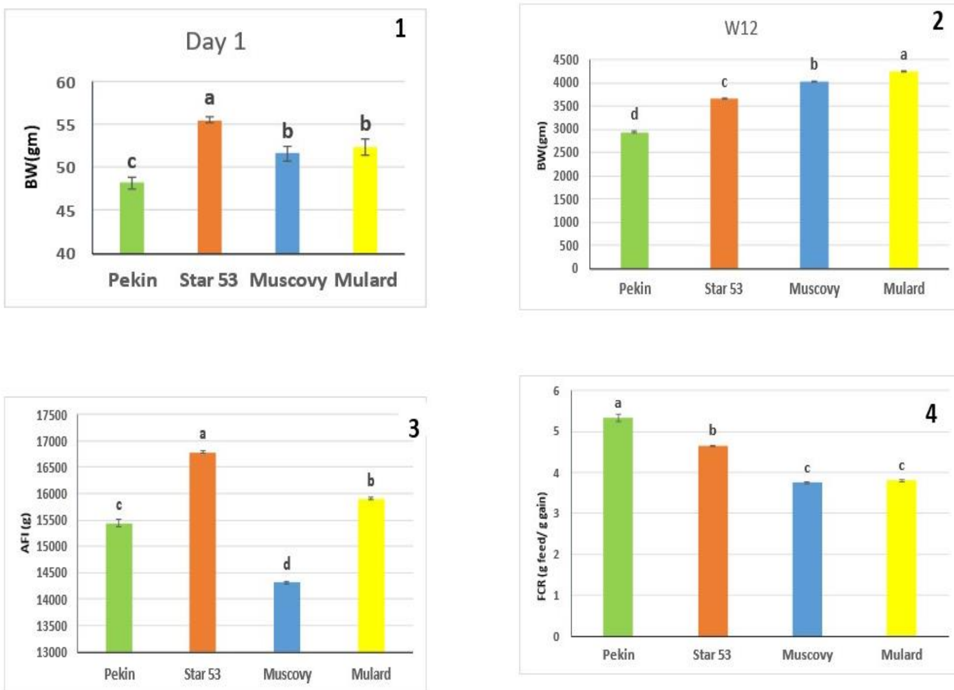

Figure1.Growth performance of Pekin, Star 53, Muscovy, and Mulard represented as (mean ± SEM). Groups with different letters are significantly different (P< 0.05). (1) Initial body weight, (2) final Body weight, (3) Average feed intake (AFI) and (4) feed conversion ratio (FCR).

The shank length, body length, keel length, and body circumference at all studied ages were affected by breed as presented in Table (2). There is no difference between Star 53,and Mulard at 2, 4, and 8 weeks of age for shank length. A similar trend was noticed at 2, 4, 6, and 8 weeks of age for body length and at 4 weeks for keel length. Star 53 had a significantly higher shank length (7.33 cm) compared to Mulard (7.05 cm), Muscovy (6.80 cm), and Pekin (6.68 cm) at 6 weeks of age. A similar trend was noticed for body length at 4 weeks of age. Concerning body circumference, and keel length, it could be noticed that the Star 53 duck had considerably greater body measurements at 2, 6, and 8 weeks of age compared to Mulrad, Muscovy, and Pekin. At12th week of age, Mulard had longer shank, body, and keel lengths (8.28, 78.50, and 20.21 cm., respectively) and also had a longer body circumference (38.60 cm). While Pekin ducks recorded shorter body, keel lengths and had a smaller body circumference (72, 15.5, and 34.5cm., respectively).

Table 2. Body measurements (Shank length, Body length, Keel length and Body circumference) for four duck breeds under investigation

Strains	Pekin	Star 53	Muscovy	Mulard	P-value
			Shank length (cm)		
2nd week	4.60±0.11^{b}	5.20±0.14^{a}	4.73±.0.03^{b}	4.92±.04^{ab}	<0.05
4th week	5.20±0.11^{c}	6.93±0.13^{a}	5.55±0.01^{b}	6.94±0.01^{a}	<0.05
6th week	6.68±0.09^{c}	7.33±0.02^{a}	6.80±0.04^{c}	7.05±0.03^{b}	<0.05
8th week	6.68±0.09^{c}	7.46±0.03^{a}	7.21±0.04^{b}	7.43±0.04^{ab}	<0.05
10th week	7.42±0.06^{c}	7.58±0.05^{b}	7.61±0.05^{b}	7.85±0.07^{a}	<0.05
12th week	7.58±0.08^{b}	7.61±0.08^{b}	7.81±0.07^{b}	8.28±0.04^{a}	<0.05
			Body length (cm)		
2nd week	35.01±0.07^{c}	38.60±0.29^{a}	36.20±0.09^{b}	38.10±0.07^{a}	<0.05
4th week	53.00±0.59^{d}	64.95±1.08^{a}	55.60±0.11^{c}	61.50±0.11^{b}	<0.05
6th week	64.95±1.08^{b}	67.45±0.40^{a}	65.30±0.36^{ab}	65.50±0.11^{ab}	<0.05
8th week	67.45±0.40^{c}	72.00±0.23^{a}	70.35±0.24^{b}	71.60±0.22^{a}	<0.05
10th week	68.70±0.11^{d}	74.55±0.11^{c}	75.75±0.099^{b}	76.47±0.05^{a}	<0.05
12th week	72.00±0.23^{d}	75.75±0.09^{c}	76.50±0.12^{b}	78.50±0.12^{a}	<0.05
			Keel length (cm)		
2nd week	4.04±0.04^{d}	5.30±0.11^{a}	4.40±0.07^{c}	5.02±0.01^{b}	<0.05
4th week	4.71±0.01^{c}	9.05±0.31^{a}	8.32±0.03^{b}	8.82±0.06^{ab}	<0.05
6th week	8.43±0.28^{d}	14.5±0.19^{a}	10.8±0.05^{c}	12.5±0.11^{b}	<0.05
8th week	9.70±0.036^{d}	16.25±0.057^{a}	14.40±0.06^{c}	15.23±0.04^{b}	<0.05
10th week	13.93±0.18^{d}	17.6±0.11^{c}	18.08±0.03^{b}	19.05±0.03^{a}	<0.05
12th week	15.5±0.47^{c}	18.30±0.03^{b}	19.11±0.04^{b}	20.21±0.04^{a}	<0.05
			Body circumference (cm)		
2nd week	14.13±0.15^{d}	22.25±0.09^{a}	19.15±0.04^{c}	20.16±0.04^{b}	<0.05
4th week	22.25±0.099^{d}	32.24±0.047^{a}	27.25±0.34^{c}	29.70±0.11^{b}	<0.05
6th week	28.30±0.03^{d}	32.80±0.09^{a}	29.07±0.11^{c}	31.02±0.09^{b}	<0.05
8th week	32.80±0.092^{c}	33.80±0.15^{a}	32.60±0.11^{c}	33.30± 0.11^{b}	<0.05
10th week	33.80±0.15^{d}	34.50±0.11^{c}	36.50±0.11^{b}	37.60±0.11^{a}	<0.05
12th week	34.50±0.11^{d}	36.50±0.11^{c}	37.60±0.11^{b}	38.60±0.11^{a}	<0.05

There was significant diversity in biochemical parameters between the four duck breeds. The results revealed that the highest values of Glucose, HDL, LDL, Globulin, and MDA wereobserved in Mulard ducks. While Pekin ducks recorded the highest value of Total cholesterol, Triglyceride, alanine aminotransferase (ALT), SOD, and GPX.The lowest values of total protein, Globulin and GPX were recorded in Star 53. Muscovy ducks showed the highest level of uric acid, Total protein and albumin Table (3).

Table 3.The effect of Duck breeds reared under the same environmental conditions ontheir biochemical parameters at 12th week of age

Parameters	Pekin	Star 53	Muscovy	Mulard	P-value
Glucose(mg/dL)	142.33±0.21^d	152±0.86^c	163.5±0.43^b	172±0.86^a	< 0.001
uric acid(mg/dL)	3.20±0.04^d	9.82±0.31^c	24.5±0.34^a	12.17±0.17^b	< 0.001
Total cholesterol(mg/dL)	202.67±0.88^a	150.5±0.22^d	167.83±1.9^c	195.67±0.80^b	< 0.001
HDL (mg/dL)	50.00±0.37^b	50.00±0.00^b	38.17±0.17^c	62.83±0.70^a	< 0.001
LDL (mg/dL)	150.17±0.60^b	100.50±0.22^c	67.67±0.61^d	260.00±1.37^a	< 0.001
Triglyceride(mg/dL)	153.17±0.17^a	142.33±0.21^b	131.17±0.4^c	61.67±0.42^d	< 0.001
Total protein (g/dl)	3.77±0.02^b	1.13±0.11^c	5.43±0.17^a	5.7±0.04^a	< 0.001
Albumin(g/dl)	1.80±0.04^c	0.67±0.07^d	3.25±0.18^a	2.62±0.06^b	< 0.001
Globulin(g/dl)	1.85±0.01^c	0.40±0.02^d	2.25±0.06^b	3.22±0.05^a	< 0.001
A/G ratio	0.97±0.02^b	1.67±0.18^a	1.45±0.09^a	0.81±0.02^b	< 0.001
ALT(g/dl)	38.50±0.01^a	24.62±0.15^b	15.17±0.17^c	24.17±0.17^b	< 0.001
AST(g/dl)	57.50±0.02^b	82.17±0.31^a	21.5±0.34^c	19.17±0.17^d	< 0.001
ALP(g/dl)	167.17±0.6	154.00±0.63	170.67±0.6	169.33±18.27	>0.05^{NS}
SOD(U/mL)	132.00±0.26^a	63±0.58^b	6.23±0.24^c	5.35±0.19^c	< 0.001
GPX(U/mL)	267.00±0.37^a	24.17±0.17^d	134.67±1.2^c	142.33±0.67^b	< 0.001
MDA (nmol/L)	4.18±0.05^d	10.17±0.17^c	17.50±0.34^b	26.17±0.31^a	< 0.001

^{abcd} Means with different superscript within same row are statistically significant; statistical significance p <0.001., NS: not significant. HDL: high density lipoprotein; LDL: low density lipoprotein; ptn: protein; A/G: albumin to globulin; ALT: alanine aminotransferase; AST: aspartate aminotransferase; ALP: alkaline Phosphatase; SOD: superoxide dismutase; GPX: glutathione peroxidase; MDA: malondialdehyde.

Breast meat color and quality characteristics of four duck breeds was represented in Table (4). Duck breeds had an important influence on color values for Lightness (L*), Redness (a*), and Yellowness (b*). Muscovy duck had higher (a*) and (b*) values (13.12 and 11.23) than other breeds and the lowest (L*) value (45.33). The lowest a* value was recorded for the Pekin duck (7.82). Mulard duck had the lowest WHC (45.33%) with the highest drip loss (3.8%) and cooking loss (24.4%). The highest WHC (72.67%), PH (6.84), and TBARS (0.32 mg/kg) were denoted for Star 53 ducks. While the highest shear force value (20.77 kg) wasshown in Pekin ducks. Muscovy ducks hadthe lowest cooking loss, shear force, and TBARS.

Table 4.comparative breast meat color and quality characteristics of four duck breeds

Parameters	Pekin	Star 53	Muscovy	Mulard	P-value
pH	6.15 ± 0.01^{b}	6.84 ± 0.03^{a}	5.74 ± 0.01^{c}	5.73 ± 0.03^{c}	< 0.001
L*	47.50 ± 0.22^{c}	55.77 ± 0.05^{a}	45.33 ± 0.33^{d}	51.77 ± 0.05^{b}	< 0.001
a*	7.82 ± 0.09^{d}	10.72 ± 0.05^{b}	13.12 ± 0.02^{a}	10.30 ± 0.04^{c}	< 0.001
b*	2.23 ± 0.12^{c}	2.35 ± 0.1^{c}	11.23 ± 0.02^{a}	4.35 ± 0.1^{b}	< 0.001
WHC (%)	61.00 ± 0.37^{b}	72.67 ± 0.21^{a}	47.17 ± 0.31^{c}	45.33 ± 0.21^{d}	< 0.001
Drip loss (%)	1.47 ± 0.02^{c}	1.23 ± 0.05^{d}	1.76 ± 0.00^{b}	3.80 ± 0.04^{a}	< 0.001
Cooking loss (%)	21.97 ± 0.11^{b}	19.43 ± 0.15^{c}	10.43 ± 0.06^{d}	$24.40\pm.07^{a}$	< 0.001
shear force (kg/cm^2)	20.77 ± 0.22^{a}	$18.47\pm.14^{b}$	10.87 ± 0.3^{d}	14.17 ± 0.13^{c}	< 0.001
TBARS (mg/kg)	0.21 ± 0.01^{b}	0.32 ± 0.01^{a}	0.12 ± 0.01^{c}	0.25 ± 0.01^{b}	< 0.001

[abcd] Means with different superscript within same row are statistically significant; statistical significance < 0.001; b*: Yellowness; L*: Lightness; a*: redness; WHC: water holding capacity; PH: Potential of hydrogen; TBARS: Thiobarbituric Acid Reducing Substances.

Thigh meat color and quality characteristics of four duck breeds were presented in Table (5). Duck breeds had a significant effect on color values for Lightness (L*), Redness (a*), and Yellowness (b*). Muscovy duck had higher (a*) and (b*) values (11.4 and 10.6) than other breeds and the lowest (L*) value (44.4). The lowest a* value was recorded for the Pekin duck (5.82). Mulard duck hadthe highest drip loss (2.12%) and cooking loss (31.17%). The highest WHC (73.7%) and PH (7.84) were denoted for Star 53 ducks. While the highest shear force value (20.8 kg) wasshown in Pekin ducks. Muscovy ducks had the lowest shear force and TBARS.

Table 5. Thigh meat color and quality characteristics among different investigatedduck breeds.

Parameters	Pekin	Star 53	Muscovy	Mulard	P-value
pH	7.15 ± 0.009^{b}	7.84 ± 0.028^{a}	5.89 ± 0.026^{c}	5.92 ± 0.018^{c}	< 0.001
L*	48.60 ± 0.24^{c}	50.60 ± 0.13^{b}	44.40 ± 0.04^{d}	51.8 ± 0.05^{a}	< 0.001
a*	5.82 ± 0.09^{d}	8.72 ± 0.05^{c}	11.4 ± 0.08^{a}	10.30 ± 0.045^{b}	< 0.001
b*	2.50 ± 0.12^{c}	2.65 ± 0.09^{c}	10.60 ± 0.06^{a}	4.35 ± 0.096^{b}	< 0.001
WHC (%)	62.00 ± 0.37^{b}	73.70 ± 0.21^{a}	47.50 ± 0.23^{c}	48.17 ± 0.17^{c}	< 0.001
Drip loss (%)	1.47 ± 0.02^{bc}	1.23 ± 0.05^{c}	1.72 ± 0.004^{b}	2.12 ± 0.19^{a}	< 0.001
Cooking loss (%)	19.40 ± 0.15^{b}	15.45 ± 0.07^{c}	15.45 ± 0.07^{c}	31.17 ± 0.20^{a}	< 0.001
shear force (kg/cm^2)	20.8 ± 0.22^{a}	18.47 ± 0.14^{b}	11.43 ± 0.20^{d}	14.67 ± 0.15^{c}	< 0.001
TBARS (mg/kg)	0.21 ± 0.013^{b}	0.317 ± 0.015^{a}	0.14 ± 0.011^{c}	0.28 ± 0.013^{a}	< 0.001

[abcd] Means with different superscript within same row are statistically significant; statistical significance < 0.001; b*: Yellowness; L*: Lightness; a*: redness; WHC: water holding capacity; PH: Potential of hydrogen; TBARS: Thio-barbituric Acid Reducing Substances.

GH, *IGF1* and Calpain genes expression in four duck breedswas revealed(Figure 2). The Mulard hadconsiderably ($p<0.05$) increased expression of *GH*, *IGF1* than other breeds. In contrast,Muscovy recorded noticeably ($p<0.05$) increased expression of the Calpain gene than Mulard, Star 53, and Pekin duck.

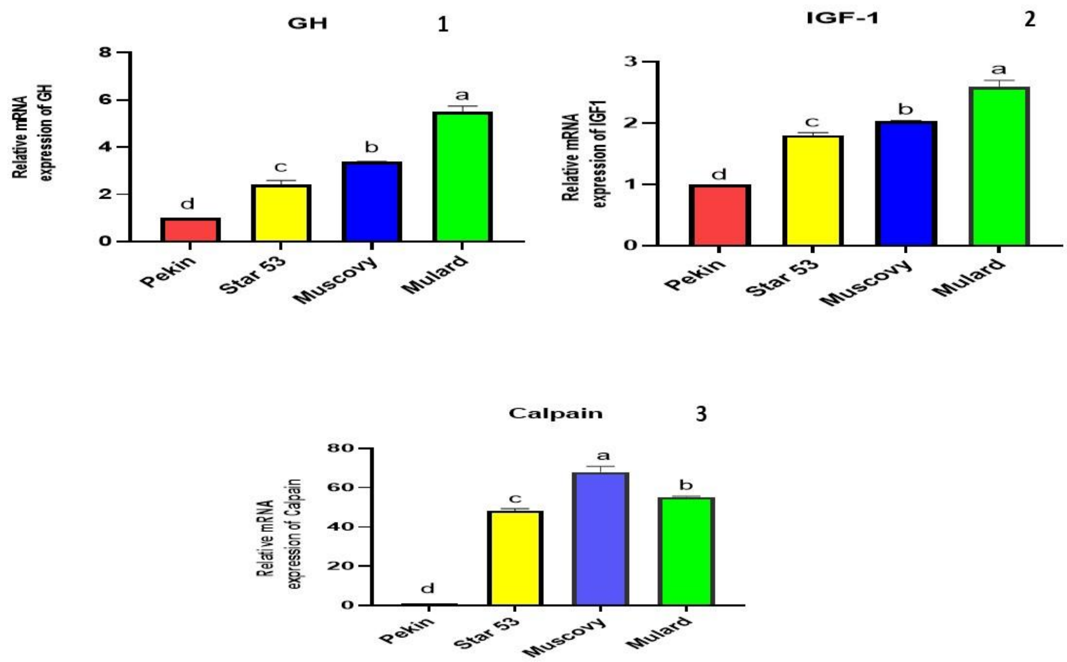

Figure 2. Graphical presentation of real-time quantitative PCR analysis of the expression of (1) *GH* (Growth Hormone), (2) *IGF-1*(Insulin growth factor-1) and (3) *Calpain* genes in breast Muscles of different duck breeds (mean ± SEM) at 12thweek. Groups with different letters are significantly different (P< 0.05, one-way ANOVA).

Discussion

The present experiment studied the breed effects on productive traits, biochemical parameters, meat quality, and gene expression of Pekin, Star 53, Muscovy, and Mulard ducks to investigate the greatest breed with the best qualities. This study demonstrated that the Mulard has the highest BWthan other breeds. These results were in agreement with those reported by Omar *et al.*[37], and Nasr *et al.* [38] who stated that Mulard was 4,021 g at the 10th week of age. On the contrary, Galal *et al.*[3], and Hassan *et al.* [39]reported that the Muscovy showed the highest BW. However, Star 53 breed was higher than Mulard ducks which were slaughtered at the 8th week of age [40]. The result of feed intake was contrary to Galal *et al.*[3] who reported that Muscovy consumedlarger feed than Pekin ducks. Also, Abdel –Rahman and Mosaad[41] showed that feed consumption for Muscovy ducks was 25.419 kg/ duck. However, Hassan*et al.* [39]stated that Muscovy consumes the lowest amount of feed whichwas consistent with our study.The significant variations between different breeds in productive traits could be attributed to differences in genetic makeup [42].

Body measurements were obviously influenced by breeding and rise with age. The shank length of Star 53, Mulard, Muscovy, and Pekin at 6 weeks measured 7.33 cm, 7.05 cm, 6.80 cm, and 6.68 cm, respectively. Therefore, Star 53 had a longer shank length than other strains. These results were in disagreement with Makram *et al.* [26] who recorded that the Pekin duck had a longer shank length (6.65 cm) than Muscovy (6.09 cm). While Makram *et al.* [43] found that the Muscovy duck had higher sexual dimorphism for shank length compared to Pekin ducks. The difference between different breeds in shank length was related to a positivecorrelation between BW and shank length [10]. Mulard duck had significantly higher BW, body circumference and body length, keel length and shank at 12th week of age compared with Star 53, Muscovy, and Pekin ducks.There was a positive relationship between chest circumference and BW[44]. Książkiewicz and Mazanowski[45] reported breast circumference in Mulard was 40.15 cm at 12th week of age which is in accordance with our study. While Muscovy ducklings had larger breast circumference, keel length, and shank length at 4 to 12thweeks of age than Sudani ducklings [46]. The difference in body measurement between breeds suggests distinct and unique in terms of body biometric characteristics[47].

Biochemical parameters were critical tools for predicting metabolic disorders [48]**.** The blood changed when the bird was under stress due to thermoregulatory mechanisms [49]. ALT and triglyceride values of Pekin duck were in contradiction with those ofArak *et al***.** [50] who mentioned that ALT and triglyceride values were 155.16 mg/dl and 46.64 IU/L, respectively.Total cholesterolin Pekin was higher than in other breeds which may be attributable to the increased production of cholesterol by the liver and decreased mobilization by tissues[51].Lower concentrations of total proteins in Star 53 may be a consequence of higher protein and amino acid requirements for somatic development. Similar findings have been found in chickens and guinea fowl **[**52,53].The values of biochemical parameters for Muscovy and Mulardagreed withNasr*et al.*[38].Also, the results of total proteins, albumin, and globulin for Mulard were comparable with those reported byOmar*et al.*[37]but Muscovy values were consistent with that reported by previous researchers [49]. On the contrary, El-Fiky*et al.*[54]found that values of HDL in Muscovy (83.40 mg/dl) were higher than in Mulard (77.47 mg/dl). Free radicals and other reactive oxygen species cause cell destruction, and antioxidant capacity contributes to decreasingoxidative stress “the imbalance between reactive oxygen species and antioxidants” [55].

In the antioxidant system, superoxide dismutaseoperated as the initial line of protection against damage by converting oxygen free radicals into hydrogen peroxide (H_2O_2). GPXwasregarded as a critical peroxide breakdown enzyme and prevented additional oxidative damage which eliminatedH_2O_2 and lipid peroxides [56]. The values of serum SOD, and GPX in Pekin were inline with those reported byAo and Kim [57]. Pekin ducks had the highest blood serum levels of SOD and GPX enzymes than other breeds andwere thought to be more oxidative stress tolerant and enhance immune function [58,59]. MDA was considered a radical oxidative marker and one of the byproducts of lipid peroxidation in cell membranes and its content could be used to assess the threshold of oxidative stress in an organism[60]. Values of antioxidant enzymes for Muscovy and Mulardagreedwith Nasr*et al.* [38]. Variation in antioxidant breedsmay be possible due to genetic regulationsuggestingtheselective breeding of ducks for new strains with higher oxidative stress tolerance.

Muscle lactic acid was a pH indicator, and high accumulations of it resulted in lower meat quality [61]. The pH of Muscovy meat (breast and thigh) was between 5.74 and 5.89[62-64]and was lower than those reported byNasr *et al.*[38].There was no considerable alteration in the pH of Muscovy and Mulard and these results were maintained by others[65].The valueobtained forthe pH of breast Pekin was similar to those reported previously [66]and higher than those found byHuda *et al.*[67], and Michalczuk*et al.* [68].While the pH for Star 53 breast meat was in accordance with Kokoszyński*et al.* [69]and lower than those obtained by [70]. Additionally, we noticed that the highest pH value in Star 53 breast and thighwas due to the lowest glycogenleading to improved meat shelf life[71]. In general, variations in pH values can be attributed to variations in the levels of glycogen at slaughter, reactions to stress before slaughter, or slaughter weight.

Meat colorwas used as a guide for meat quality and freshness [72], and directly associated with the ultimate pH [73]. The color of meatwas primarily influenced by the myoglobin content and nature, the composition, and the physical state of muscle [74,75]. L*, a*, and b* colors of the breast and thigh muscle of star 53 duck agreed with those reported previously [70]. While the values of Pekin were similar to those reported byKokoszyński*et al.*[76]and were lower than those reported byZheng*et al.*[65]. Muscovy values were similar to those reported by Zhu*et al.*[64] and disagree with others [65].Mulardbreast values disagreed with Zheng*et al.* [65] recorded L*, a*,and b* values (37.87, 19.91, and 7.5, respectively) at 70 days of age.In this study, the Muscovy duck had the highest redness color and lowest lightness than other breeds.These findings did not support those reported previously [3,77]in which the Muscovy ducks had lighter breast muscles (L*) than Pekin ducks. The lowest L* value in Muscovy duck breast and thighexplained the associationbetween iron concentration and meat color, which was described in an earlier study ofKokoszyński*et al.*[47]. Significantly superior redness values were documented for the breast meat of Muscovy compared to Mulard ducks, and this was confirmed in an earlier study [65]. In contrast, the meat of Muscovy ducks was recorded to be graded lower for color, compared with the breast meat of Rouen ducks [78]. This difference could be related to the age at which ducks are slaughtered.

Water holding capacitymeans the ability of meat to retain water. Water will flow out gradually from the myofibril enhancing the length of postmortem time [79].WHC% breast and thigh in Pekin and Muscovy were similar to those found byHuda *et al.*[67]. While Mulard duck breast was lower than Janiszewski *et al.* [80].The difference in WHCwithin the breed was supported by the findings of other researchers [62,67,68]. The present investigation revealed that Star 53 duck had the highest value, and this may be attributable to differences in genotype and muscle fiber sizes [81].A greater WHC was very essential for the food industry, as it could contribute positively to lowering the final product weight loss that happened during storage [67].

Drip loss referred to the percentage of water lost from meat and was considered an indirect marker of WHCsubsequently, drip loss wasadversely correlated with WHC [72].Drip loss values for Muscovy, Pekin, and Mulard were lower than reported byEratalar*et al.*[70]. While Star 53 drip loss disagreed withKokoszyński*et al.*[82].Drip loss increased in Mulard ducks,which was supported byNasr*et al.*[38], and Zheng*et al.*[65].The highest drip loss in Mulard may be due to low pH whichpromotes muscle fiber contraction, producing high drip loss [83]. The meat from Mulards had considerable quantities of free water, which suggestedit was not very suitable for processing [62].

Cooking loss declined when the WHC was higher. The cooking loss of Pekin and Muscovy was contrary tothe previous[67]. While Mulard disagreed withZheng*et al.*[65]. The meatof Muscovy had the lowest cooking loss value followed by Star 53, Pekin, and Mulard.These findings were supported by Pingel [84], andBaeza *et al.* [85] who reported that the Muscovy ducks were characterized as meat of better quality than Pekin ducks. On the contrary,Wawro*et al.*[62], andOmojola[78] showed that Pekin ducksrevealedsuperior meat quality. The amount of water reserved in meat after cookinghas been related to the juiciness, palatability, and marketable weight of the products [86].

Another meat trait that was significant to consumers and processors was tenderness, which was evaluated using shear force values[67].There was a significant difference in Shear force values among breeds. These resultswere supported byOmojola[78]. However, another researcher didn’tobserveany difference due to strain (Pekin, Muscovy, or their crossbred offspring) [57,77].In this study, Shear force values for Pekin and Muscovy were higher than those reported byOmojola[78]. Muscovy recorded the lowest shear force. However, Pekin noted the highest value.These results disagreed with Kokoszyński*et al.*[76], andOmojola[78] reported that the shear force in Pekin was lower than in Muscovy. These authors recorded shear force in Pekin ducks a 7 weeks and 12 weeks of age in Muscovy. A greater shear force in Pekinmay be associated with the growth of the muscle tissue because the cross-sectional area of muscle fiber was enhancedwith age [87].

The development of off flavors (rancidity) was due to lipid oxidation, which could be determined by measurement of the degradation products such as thio-barbituric acid reactive substance [88]. Undesirable changes during storage at both refrigeration and freezing temperatures for long storage periods lead to lipid deterioration and liberation of free fatty acids [89]. The Value of TBARS in Pekin was similar to that reported by Jeong [66]. While in Muscovy was contradictory with Zhu*et al.*[64] who stated that the TBARSfrom breast meat of Muscovy ducks was 2.82 mg/kg and 1.36 mg/kg for thigh meat.

*GH and IGF-1*were candidate somatotropic axis genes that improvedgrowth performance and carcass trait characteristics in chickens [90,91].*GH* gene was a great genetic marker for improving the genetic potential of ducks [92].*IGF-1*was a potential gene for chickens' growth, body composition, metabolism, skeletal features, development of adipose tissue, and fat deposition [93]. The current results demonstrated considerable variations in *GH* and *IGF-1* expression amongst the different breeds. These findings were supported by others[94,95]. The Mulard exhibited the highest expression, which may explain why it had greater muscular growth. IGF-1 gene expression findings differ from those of Hassan*et al.*[39], who reported that Muscovy ducks had the most significant *IGF-1* gene expression, followed by

Mulard and Pekin ducks. This difference was related to a positive correlation between *IGF-1* concentration and body weight[96]. Transgenic over-expression of *IGF-1* in mice had shown that *IGF-1* mRNA expression wascorrelated with enlarged body weight. Body weight increased by 30% when *IGF-1* was overexpressed at 1.5 times the normal levels [97]. Furthermore,Wang *et al.*[98] showed that the *IGF-1* gene is tightly linked to both the body size and weight of chickens.

The Calpain gene was especially connected to connective muscle in areas where proteolysis had been related to post-mortem meat tenderness [99]. Also,Gandolfi *et al.*[100]reported that elevated calpain activity stimulated the cleavage of certain myofibrillar proteins such as titin, desmin, and vinculin,which enhanced tenderness.Piórkowska*et al.* [101] referred to the primary determinant of meat tenderness as a shear force. A low shear force revealed tender or soft meat. High shear force indicates that the meat has low proteolytic activity which is correlated with its hardness. Previous studies have shown a close connection between the calpain system and the qualities of pig meat [100], sheep [102], and chicken [103]. In this study, it was observed that the level of the Calpain gene was higher in Muscovy ducks. This breed was characterized by lower shear force. These results were consistent with previous [101] which reported that the Calpain gene was expressed at a lower level in birds with high shear force (low tenderness) than in broilers with low shear force.Contradicting our findings byLiao and Chou [104] that the difference in meat tenderness between Muscovy and Pekin duck muscles was caused by quicker calpain-1 activation in postmortem Pekin breast muscles,this might indicate that calpain is involved in the tenderization process of duck breast muscle. These findings were confirmed by the studies of other researchers regarding the role of calpain in postmortem tenderization[24,105-107],and goose [108].

Conclusions

This study revealed that Mulard ducks had the highest productive traits andhigh expression of GH, and IGF1. Muscovy ducks had better meat quality and high expression of the Calpain gene. This illuminates the crucial role played by conventional breeding programs in influencing molecular genetic systems that result in improved genotypes with potential productive qualitiesand meat quality.

Conflict of interest

There are no conflicts of interest among the authors to reveal.

References

[1] FAOSTAT.(2019): Available online: http://www.fao.org/faostat/en/#data (accessed on 15 December 2019).

[2] El-Soukkary, F.A.; Mohamed, H.M.; Dawood, A.A. and Abd-El Sayed, S.Y. (2005): Physico-chemical, microbiological and lipid characteristics of duck meat. Minufiya J Agric Res, 30: 527-548.

[3] Galal, A.; Ali, W.A. H.; Ahmed, A.M.H. and Ali, K.A. (2011): Performance and carcass characteristics of Dumyati, Muscovy, Peking, and Sudani duck breeds. Egypt J Anim Prod, 48(2): 191-202.

[4] Crawford, R.D. (1990): Origin and history of poultry species. Developments in Animal and Veterinary Sciences (Netherlands).

[5] Pingel, H. (2004): Duck and geese production. World Poult, 20(8): 26-28.
[6] Lin, F.B.; Zhu, F.; Hao, J.P.; Yang, F.X. and Hou, Z.C. (2018): In vivo prediction of the carcass fatness using live body measurements in Pekin ducks. Poult Sci, 97(7): 2365-2371.
[7] Xu, T.S.; Liu, X.L.; Huang, W. and Hou, S.S. (2011): Estimates of genetic parameters for body weight and carcass composition in pekin ducks. JAnimVet Adv. 10(1): 23-28.
[8] Wu, X.; Yan, M. J.; Lian, S. Y.; Liu, X. T. and Li, A. (2014): GH gene polymorphisms and expression associated with egg laying in Muscovy ducks (*Cairinamoschata*). Hereditas, 151(1): 14-19.
[9] Wawro, K.; Bochno, R. andWilkiewicz-Wawro, E. (2001): Slaughter value of crossbred ducks (Muscovy x Pekin) slaughtered at a different age. Nat Sci, 8: 17-25.
[10] Lerner, I.M. (1937): Shank length as a criterion of inherent size. Poult Sci, 16(4): 213–215.
[11] Fitzhugh Jr, H.A. (1976): Analysis of growth curves and strategies for altering their shape. J Anim Sci, 42(4): 1036-1051.
[12] Bulgarella, M.; Wilson, R.E.; Kopuchian, C.; Valqui, T. and McCracken, K.G. (2007): Elevational variation in body size of crested ducks (*Lophonettaspecularioides*) from the central high Andes, Mendoza, and Patagonia. OrnitolNeotrop, 18: 587–602.
[13] Ologbose, F. and Samuel, D.K. (2021): Breeds, age and sex effect on hematological and biochemical parameters of ducks in rivers state, Nigeria. BSJ Agri, 4(2): 52-57.
[14] Lee, C.Y.; Lee, H.P.; Jeong, J.H.; Baik, K.H.; Jin, S.K.; Lee, J.H. and Sohn, S.H. (2002): Effects of restricted feeding, low-energy diet, and implantation of trenbolone acetate plus estradiol on growth, carcass traits, and circulating concentrations of insulin-like growth factor (IGF)-I and IGF-binding protein-3 in finishing barrows. J Anim Sci, 80(1): 84-93.
[15] Yun, J.S.; Seo, D.S.; Rhee, M.S.; Oh, S.; Kim, B.C. and Ko, Y. (2003): Relationships of concentrations of endocrine factors at antemortem and postmortem periods to carcass weight and backfat thickness in pigs. Asian australas J Anim Sci, 16(3): 335-341.
[16] Bass, J.; Oldham, J.; Sharma, M. and Kambadur, R. (1999): Growth factors controlling muscle development. Domest Anim Endocrinol, 17(2-3): 191-197.
[17] Guler, H.P.; Zapf, J.N.; Scheiwiller, E. and Froesch, E.R. (1988): Recombinant human insulin-like growth factor I stimulates growth and has distinct effects on organ size in hypophysectomized rats. Proc Natl Acad Sci, 85(13): 4889-4893.
[18] Dodson, M.V.; Hossner, K.L.; Vierck, J.L.; Mathison, B. and Krabbenhoft, E. (1996): Correlation of serum GH and IGF-1 with satellite cell responsiveness in Targhee rams. Anim Sci, 62(1): 89-96.
[19] Florini, J. R.; Ewton, D. Z. and Coolican, S. A. (1996): Growth hormone and the insulin-like growth factor system in myogenesis. Endocr Rev, 17(5): 481-517.
[20] Khan, M.A.; Ali, S.; Abid, M.; Cao, J.; Jabbar, S.; Tume, R.K. and Zhou, G. (2014): Improved duck meat quality by application of high pressure and heat: A study of water mobility and compartmentalization, protein denaturation and textural properties. Food Res. Int, 62: 926-933.
[21] An, K.A.; Arshad, M.S.; Jo, Y.; Chung, N. and Kwon, J.H. (2017): E-beam

irradiation for improving the microbiological quality of smoked duck meat with minimum effects on physicochemical properties during storage. J Food Sci, 82(4): 865-872.

[22] Koohmaraie, M. and Geesink, G.H. (2006): Contribution of postmortem muscle biochemistry to the delivery of consistent meat quality with particular focus on the calpain system. Meat Sci, 74(1): 34-43.

[23] Lee, H.L.; Santé-Lhoutellier, V.; Vigouroux, S.; Briand, Y. and Briand, M. (2008): Role of calpains in postmortem proteolysis in chicken muscle. Poult. Sci, 87(10): 2126-2132.

[24] Liu, J.; Ruusunen, M.; Puolanne, E. and Ertbjerg, P. (2014): Effect of pre-rigor temperature incubation on sarcoplasmic protein solubility, calpain activity and meat properties in porcine muscle. LWT-Food SciTechnol, 55(2): 483-489.

[25] National research council (NRC) (1994): nutrient requirements of poultry (9th Rev. Ed.), National Academy Press, Washington, DC, USA.

[26] Makram, A.; Galal, A. and El-Attar, A. H. (2017): Comparative Study on Phenotypic Parameters of Sudani, Muscovy and Pekin ducks in Egypt. The7international Conference of Sustainable Agricultural Development, 257-268.

[27]Korkeala, H.; Mäki-Petäys, O.; Alanko, T. and Sorvettula, O. (1986): Determination of pH in meat. Meat Sci, 18(2): 121-132.

[28] Hijazeen, M.; Lee, E.; Mendoka, A. and Ahn, D. (2016): Effect of Oregano essential oil (*Origanum vulgare* subsp. hirtum) on the storage stability and quality parameters of ground chicken breast meat. Antioxidants, 5(2): 1-11.

[29] Tarnauceanu, G. and Pop, C. (2016): Water holding capacity of rabbit meat (Belgian giant breed). Bulletin of University of Agricultural Sciences and Veterinary Medicine. Anim Sci Biotechnol, 73: 111-112.

[30] Demirok, E.; Veluz, V.; Stuyvenberg, W.; Castañeda, M.; Byrd, A. and Alvarado, C. (2013): Quality and safety of broiler meat in various chilling systems. Poult Sci, 92(4): 1117-1126.

[31] Horwitz, W.and Latimer, G. (2005): Official methods of analysis of AOAC International. 18th Edition, Association of Official Analytical Chemistry International, Maryland.

[32] Zhuang, H.; Savage, E.M.; Smith, D.P. and Berrang, M.E. (2009): Effect of dry-air chilling on sensory descriptive profiles of cooked broiler breast meat deboned four hours after the initiation of chilling. Poult Sci, 88(6): 1282-1291.

[33] Egyptian Organization for Standardization (ES). (2006): Methods of analysis and testing for meat. Part 10: determination of thiobarbituric acid (TBA). ES: 63-10.

[34] Wu, X.; Liu, X.T.; Lan, J.J.; Wan, X. P.; Yan, M.J.; Lian, S.Y. and Li, A. (2016): Investigation of insulin-like growth factor-1 gene with egg-laying traits in the Muscovy duck (*Cairinamoschata*). Can J Anim Sci, 96(2): 203-214.

[35] Xu, H.; Zhang, Y.; Zou, Q.; Li, L.; Han, C.; Liu, H. and Wang, Y. (2018): Characterization of the Goose CAPN3 gene and its expression pattern in muscle tissues of sichuan white geese at different growth stages. J Poult Sci, 55(3): 172–181.

[36] Yuan, J.S.; Reed, A.; Chen, F. and Stewart, C.N. (2006): Statistical analysis of real-time PCR data. BMC Bioinform, 7,85.

[37] Omar, M.A.; Abdel-Hamid, T.M.; Esam, S. and Omar, A.E. (2019): Growth and economic performance of using Dried Tomato Pomace for Mallard Ducks.Slov Vet Res, 56: 699–706.

[38] Nasr, M. A.; Alkhedaide, A. Q.; Radwan, M.M.; Abd-El Salam, E.H.; Hussein, M.A. and El Bayomi, R.M. (2022): Growth, carcass parameters, biochemical and oxidative stress indices and meat traits of duck breeds under different stocking densities. Poult Sci, 101(9),101992.

[39] Hassan, F.A.; Roushdy, E.M.; Zaglool, A.W.; Ali, M.A. and El-Araby, I.E. (2018): Growth performance, carcass traits and economic values of Pekin, Muscovy, and Mulard ducks. Slov Vet Res, 55(20): 357-365.

[40] El-Edel, M. A.; El-kholya, S. Z. and Abou-Ismail, U. A. (2015): The effects of housing systems on behaviour, productive performance and immune response to avian influenza vaccine in three breeds of ducks. Int J Agric Innov Res, 3(5): 1496-1505.

[41] Abdel-Rahman, M.A. and Mosaad, G.M. (2013): Effect of propolis as additive on some behavioural patterns, performance and blood parameters in Muscovy broiler ducks. J Adv Vet Res, 3(2): 64-68.

[42] Damaziak, K.; Michalczuk, M.; Adamek, D.; Czapliński, M.; Niemiec, J.; Goryl, A. and Pietrzak, D. (2014): Influence of housing system on the growth and histological structure of duck muscles. SAfrJ AnimSci, 44(2): 97-109.

[43] Makram, A.; Galal, A.A. and El-Attar, A.A. (2021): A comparison of three duck strains (Pekin, Muscovy & Sudani) in Egypt for sexual dimorphism with regard to body weight, body measurements and carcass traits. J Genet Environ ResourConserv, 9: 50-57.

[44] Ogah, D.M.; Yakubu, A.; Momoh, M. O. and Dim, N.I. (2011): Relationship between some body measurements and live weight in adult Muscovy ducks using path analysis. Trakia J Sci, 9(1): 58-61.

[45] Książkiewicz, J. and Mazanowski, A. (1993): Estimation of the meatness and fatness of 9-and 12-week-old Mulard ducks on the basis of selected live body measurements. J Anim Feed Sci, 2(4): 197-206.

[46] Ali, K.A. (2005): Studies on some factors affecting duck production. PhD Thesis (Doctoral dissertation), Fac. Agric, Cairo Univ, Egypt.

[47] Kokoszyński, D., Wasilewski, R., Saleh, M., Piwczyński, D., Arpášová, H., Hrnčar, C., and Fik, M. (2019): Growth performance, body measurements, carcass and some internal organs characteristics of Pekin ducks. Animals, 9(11),963.

[48] Rotava, R.; Zanella, I.; Karkow, A.K.; Dullius, A.P.; da da Silva, L.P. and Denardin, C.C. (2008): Bioquímicasanguínea de frangos de corte alimentados com subprodutos da uva. Agrarian, 1(1): 91-104.

[49] Arieli, A.; Meltzer, A. and Berman, A. (1979): Seasonal acclimatisation in the hen. Br Poult Sci, 20(6): 505-513.

[50] Arak, H. and Torshizi, M.A.K. (2021): Comparative consequences of two sources of aflatoxins in ducklings experimental aflatoxicosis. Vet Res Forum, 12(3): 305– 311.

[51] Szabo, A.; Mezes, M.; Horn, P.; Sütő, Z.; Bázár, G. Y. and Romvari, R. (2005): Developmental dynamics of some blood biochemical parameters in the growing turkey (*Meleagris gallopavo*). Acta Vet Hung, 53(4): 397-409.

[52] Silva, P.R.L.; Freitas Neto, O.C.; Laurentiz, A.C.; Junqueira, O.M. and Fagliari, J.J. (2007): Blood serum components and serum protein test of Hybro-PG broilers of different ages. Braz J Poult Sci,9: 229-232.

[53] Sonia, C.; Rajini, R. A.; Babu, M.; Vairamuthu, S. and Sujatha, T. (2013): Serum biochemical profile in pearl

Guinea fowl. Indian Vet J, 90(1): 134-135.

[54] El-Fiky, A.A.; Zanaty, G.A.; Ali, W.A.H. and Dahrouj, A.A.F. (2019): Study on the ducks fatty liver production under the Egyptian conditions. Menoufia J Anim Poult Fish Product, 3(1): 13-27.

[55] Ruan, D.; Zhu, Y.W.; Fouad, A.M.; Yan, S.J.; Chen, W., Zhang, Y.N. and Zheng, C.T. (2019): Dietary curcumin enhances intestinal antioxidant capacity in ducklings via altering gene expression of antioxidant and key detoxification enzymes. Poult sci, 98(9): 3705-3714.

[56] Utama, D.T.; Lee, J.H.; Choi, J.H. and Lee, S.K. (2016): Antioxidant enzyme activity, iron content and lipid oxidation of raw and cooked meat of Korean native chickens and other poultry. Asian-australas J Anim Sci, 29(5): 695–701.

[57] Ao, X. and Kim, I.H. (2020): Effects of grape seed extract on performance, immunity, antioxidant capacity, and meat quality in Pekin ducks. Poult sci, 99(4): 2078-2086.

[58] Iqbal, Z.; Kamran, Z.; Sultan, J.I.; Ali, A.; Ahmad, S.; Shahzad, M.I. and Sohail, M.U. (2015): Replacement effect of vitamin E with grape polyphenols on antioxidant status, immune, and organs histopathological responses in broilers from 1-to 35-d age. J Appl Poult Res, 24(2): 127-134.

[59] Kamboh, A.A.; Arain, M.A.; Mughal, M.J.; Zaman, A.; Arain, Z.M. and Soomro, A.H. (2015): Flavonoids: Health promoting phytochemicals for animal production-a review. J Anim Health Prod, 3(1): 6-13.

[60] Yin, Y.; Han, W. and Cao, Y. (2019): Association between activities of SOD, MDA and Na+-K+-ATPase in peripheral blood of patients with acute myocardial infarction and the complication of varying degrees of arrhythmia.Hell J Cardiol, 60(6): 366-371.

[61] Chen, Y.; Aorigele, C.; Yan, F., Li, Y.; Cheng, P. and Qi, Z. (2015): Effect of production system on welfare traits, growth performance and meat quality of ducks. South African J Anim Sci, 45(2): 173-179.

[62] Wawro, K.; Wilkiewicz-Wawro, E.; Kleczek, K. and Brzozowski, W. (2004): Slaughter value and meat quality of Muscovy ducks, Pekin ducks and their crossbreeds, and evaluation of the heterosis effect. Arch Anim Breed, 47(3): 287-299.

[63] Marzoni, M.; Chiarini, R.; Castillo, A.; Romboli, I.; De Marco, M. and Schiavone, A. (2014): Effects of dietary natural antioxidant supplementation on broiler chicken and Muscovy duck meat quality. Anim Sci Pap Rep, 32(4): 359-368.

[64] Zhu, Z.; Bassey, A. P.; Cao, Y.; Du, X.; Huang, T.; Cheng, Y. and Huang, M. (2022): Meat quality and flavor evaluation of Nanjing water boiled salted duck produced by different Muscovy duck (Cairinamoschata) ingredients. Food Chem, 397: 133833.

[65] Zheng, N; Zheng, L.; Xin, Q.; Miao, Z.; Zhu, Z.; Huang, Y. (2019): Changes in antioxidant enzymes in postmortem muscle and effects on meat quality from three duck breeds during cold storage. Can J Anim Sci, 100(2): 234-243.

[66] Jeong, Y.W. (2022): Growth performance and meat quality traits of Pekin ducks fed with different amounts of pelleted *Ptecticustenebrifer*. Entomol Res, 52(7): 334-338.

[67] Huda, N.; Putra, A.A. and Ahmad, R. (2011): Proximate and physicochemical properties of Peking and Muscovy duck breasts and thighs for further processing. J. Food Agric. Environ, 9(1): 82-88.

[68] Michalczuk, M.; Damaziak, K.; Pietrzak, D.; Marzec, A.; Chmiel, M.; Adamczak, L. and Florowski, T. (2016): Influence of housing system on selected quality characteristics of duck meat. Chapter 1. Pekin duck. Annals of Warsaw University of Life Science. Anim Sci, 55(1): 89–97.

[69] Kokoszyński, D.; Wasilewski, R.; Stęczny, K.; Bernacki, Z.; Kaczmarek, K.; Saleh, M. and Biegniewska, M. (2015): Comparison of growth performance and meat traits in Pekin ducks from different genotypes. Eur Poult Sci, 79(110): 1-11.

[70] Eratalar, S.A.; Okur, N. and Yaman, A. (2022): The effects of stocking density on slaughter performance and some meat quality parameters of Pekin ducks. Arch Anim Breed, 65(2): 199-206.

[71] Ali, M.D.; Kang, G.H.; Yang, H.S.; Jeong, J.Y.; Hwang, Y.H.; Park, G.B. and Joo, S.T. (2007): A comparison of meat characteristics between duck and chicken breast. Asian-australas J Anim Sci, 20(6): 1002-1006.

[72] Cornforth, I. (1994): Color–Its basis and importance. In Pearson, A.M. and Dutsin, T.R.editors. Quality attributes and their measurements in meat Poultry and Fish Products. Advance in Meat research Series. GlassgowBlackle Academic and Professional. 33-77.

[73] Zhuang, H. and Savage, E.M. (2010): Comparisons of sensory descriptive flavor and texture profiles of cooked broiler breast fillets categorized by raw meat color lightness values1. Poult sci, 89(5): 1049-1055.

[74] Giddings, G.G. (1977): Symposiums; The basis of quality in muscle foods; the basis of color in muscle foods.

[75] Renerre, M. (1986): Influence des facteursbiologiques et technologiques sur la couleur de la viande bovine. Bull. Tech. CRZV Theix, INRA, 65: 41-45.

[76] Kokoszyński, D.; Wilkanowska, A.; Saleh, M.; Fik, M. and Bigorowski, B. (2021): Comparison of some meat and liver quality traits in Muscovy and Pekin ducks. J Appl Anim Res, 49(1): 118-124.

[77] Chartrin, P.; Meteau, K.; Juin, H.; Bernadet, M.D.; Guy, G.; Larzul, C. and Baéza, E. (2006): Effects of intramuscular fat levels on sensory characteristics of duck breast meat. Poult Sci, 85(5): 914-922.

[78] Omojola, A.B. (2007): Carcass and organoleptic characteristics of duck meat as influenced by breed and sex. Int J Poult Sci, 6(5): 329-334.

[79] Warner, R.D. (2023): The eating quality of meat: IV—Water holding capacity and juiciness. Toldra, f. editors. In Lawrie's meat science. Woodhead Publishing Series in Food Science, Technology and Nutrition.457-508.

[80]Janiszewski, P.; Murawska, D.; Hanzal, V.; Gesek, M.; Michalik, D. Zawacka, M. (2018): Carcass characteristics, meat quality, and fatty acid composition of wild-living mallards (*Anas platyrhynchos* L.). Poult Sci, 97(2): 709-715.

[81] Jaturasitha, S.; Srikanchai, T.; Kreuzer, M. and Wicke, M. (2008): Differences in carcass and meat characteristics between chicken indigenous to northern Thailand (Black-boned and Thai native) and imported extensive breeds (Bresse and Rhode Island Red). Poult Sci, 87(1): 160-169.

[82] Kokoszyński, D.; Piwczyński, D.; Arpášová, H.; Hrnčar, C.; Saleh, M. and Wasilewski, R. (2019): A comparative study of carcass characteristics and meat quality in genetic resources Pekin ducksutr., 9(1): 81-114 and commercial crossbreds. Asian Australas J Anim Sci, 32(11): 1753–1762.

[83] Tang, S.; Yu, J.; Zhang, M. and Bao, E. (2013): Effects of different heat stress periods on various blood and meat quality parameters in young Arbor Acer broiler chickens. Can J Anim Sci, 93(4): 453-460.

[84] Pingel, H. (1997): Perspective of the production of waterfowl. In 11th European Symp. On Waterfowl, Nantes, France. 128-134.

[85] Baeza, E.;Salichon, M. R.; Marche, G. and Juin, H. (1998): Effect of sex on growth, technological and organoleptic characteristics of the Muscovy duck breast muscle. Br Poult Sci, 39(3): 398-403.

[86] Strydom, P.; Lühl, J.; Kahl, C. and Hoffman, L.C. (2016): Comparison of shear force tenderness, drip and cooking loss, and ultimate muscle pH of the loin muscle among grass-fed steers of four major beef crosses slaughtered in Namibia. S Afr J Anim Sci, 46(4): 348-359.

[87] Dransfield, E. and Sosnicki, A.A. (1999): Relationship between muscle growth and poultry meat quality. Poult sci, 78(5): 743-746.

[88] Owens, C.M. (2001): Coated poultry products. In Sams, R. editors. poultry meat processing. New York: CRC Press. 237-252.

[89] Murad, H.O.M.; Al- Jaff, B.M.A. and Salih, H.H. (2013): The physiochemical quality of imported frozen chicken thighs sold in Sulaimani markets. J Tikrit Univ for AgriSci. 1stScientific Conference for Food Sciences,19: 15-23.

[90] Anh, N. T. L.; Kunhareang, S. and Duangjinda, M. (2015): Association of chicken growth hormones and insulin-like growth factor gene polymorphisms with growth performance and carcass traits in Thai broilers. Asian-australas J Anim Sci, 28(12): 1686–1695.

[91] Brahmkhatri, V.P.; Prasanna, C. and Atreya, H.S. (2015): Insulin-like growth factor system in cancer: novel targeted therapies. Biomed Res Int, 1-25.

[92] Zaglool, A.W.; Hassan, F.A.M.; Roushdy, E.M. and Abd-Elfatah, A.H. (2020): Polymorphisms in Intron 2 of Growth Hormone Gene and Their Associations with Economic Traits in Muscovy, Pekin, and Mulard Ducks. Scholars J Agric Vet Sci, 7: 41-46.

[93] Zhou, H.; Mitchell, A.D.; McMurtry, J.P.; Ashwell, C.M. and Lamont, S.J. (2005): Insulin-like growth factor-I gene polymorphism associations with growth, body composition, skeleton integrity, and metabolic traits in chickens. Poult Sci, 84(2): 212-219.

[94] Tang, Q.; Song, C.; Zhang, S.; Hu, Y.; Zhao, D. and Zou, J. (2014): Gene expression profile of IGF1 and MSTN mRNA and their correlation with carcass traits in different breeds of geese at 70 d of age. Br Poult Sci, 55(1): 76-80.

[95] Jia, J.; Ahmed, I.; Liu, L.; Liu, Y.; Xu, Z.; Duan, X. and Ge, C. (2018): Selection for growth rate and body size have altered the expression profiles of somatotropic axis genes in chickens. PLoS One, 13(4): e0195378.

[96] Siddiqui, R.A.; McCutcheon, S.N.; Blair, H.T.; Mackenzie, D.D.; Morel, P.C.; Breier, B. H. and Gluckman, P. D. (1992): Growth allometry of organs, muscles and bones in mice from lines divergently selected on the basis of plasma insulin-like growth factor-I. GDA, 56(1): 53-60.

[97] Mathews, L.S.; Hammer, R.E.; Behringer, R.R.; D'ercole, A.J.; Bell, G.I.; Brinster, R.L. and Palmiter, R. D. (1988): Growth enhancement of transgenic mice expressing human insulin-like growth factor I. Endocrinology, 123(6): 2827-2833.

[98] Wang, W.; Ouyang, K.; Ouyang, J.; Li, H.; Lin, S. and Sun, H. (2004): Polymorphism of insulin-like growth factor I gene in six chicken breeds and its relationship with growth traits. Asian-australas J Anim Sci, 17(3): 301-304.

[99] Bhat, Z.F.; Morton, J.D.; Mason, S.L. and Bekhit, A.E.D.A. (2018): Role of calpain system in meat tenderness: A review. Food Sci Hum Wellness, 7(3): 196-204.

[100] Gandolfi, G., Pomponio, L., Ertbjerg, P., Karlsson, A. H., Costa, L. N., Lametsch, R. and Davoli, R. (2011): Investigation on CAST, CAPN1 and CAPN3 porcine gene polymorphisms and expression in relation to post-mortem calpain activity in muscle and meat quality. Meat Sci, 88(4): 694-700.

[101] Piórkowska, K.; Nowak, J. and Połtowicz, K. (2015): The normalisation of CAPN gene expression in M. pectoralis superficialis in broiler lines differing in growth rate and their relationship to breast muscle tenderness. Br Poult Sci, 56(4): 452-458.

[102] Grochowska, E.; Borys, B.; Grześkowiak, E. and Mroczkowski, S. (2017): Effect of the calpain small subunit 1 gene (CAPNS1) polymorphism on meat quality traits in sheep. Small Rumin Res, 150: 15-21.

[103] Zhang, Z.R.; Liu, Y.P.; Yao, Y.G.; Jiang, X.S.; Du, H.R. and Zhu, Q. (2009): Identification and association of the single nucleotide polymorphisms in calpain3 (CAPN3) gene with carcass traits in chickens. BMC Genetics, 10(1): 1-7.

[104] Liao, C.C. and Chou, R.G.R. (2014): Comparison of postmortem proteolysis between Pekin and Muscovy duck breast muscles. J Sci Food Agric, 94(14): 2846-2849.

[105] Koohmaraie, M. (1996): Biochemical factors regulating the toughening and tenderization processes of meat. Meat Sci, 43: 193-201.

[106] Melody, J.L.; Lonergan, S.M.; Rowe, L.J.; Huiatt, T.W.; Mayes, M.S. and Huff-Lonergan, E. (2004): Early postmortem biochemical factors influence tenderness and water-holding capacity of three porcine muscles. J Anim Sci, 82(4): 1195-1205.

[107] Chang, Y.S. and Chou, R.G.R. (2012): Postmortem role of calpains in Pekin duck skeletal muscles. J Sci Food Agric, 92(8): 1620-1626.

[108] Chang, Y.S.; Stromer, M.H. and Chou, R.G.R. (2019): Postmortem role of calpain in Chinese and Wuzong goose muscles. Poult Sci, 98(12): 7151-7157.

الملخص العربي

الصفات الانتاجية والقياسات البيوكيميائية وجودة اللحوم والتعبير الجينيلهذه الصفات فى سلالات البط المختلفة

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تهدف هذه الدراسة إلى تقييم الصفات الإنتاجية والقياسات الكيميائية الحيوية وجودة اللحوم والتعبير الجيني لهرمون النمو (GH)وجين (IGF-1) وجين (Calpain) فى اربعة سلالات من البط [االبكينيوالفرنساوي البيوروالمسكوفى والبغالى.]أجريت هذه التجربة على 80 بطة (20 من كل سلالة) ولقد تم وضعهم تحت نفس الظروف البيئية والرعاية من عمر يوم واحد حتى نهاية التجربة (الأسبوع الثاني عشر من العمر). حيث تم تقييم أداء النمو وقياس تحاليل الدم البيوكيميائية وجودة اللحوم والتعبير الجينى لجينات النمو وجين (Calpain).أظهرت النتائج أن البط البغالى أعلى نمو للجسم من السلالات الاخرى بينما البط البكينى كان أعلاهم في معامل التحويل الغذائى. بالاضافةْ إلى ذلك أظهر البط البغالى أعلى قياسات للجسم فى نهاية التجربة. عند قياس تحاليل الدم البيوكيمائية كانت معدلات (TC) ,(SOD),(GPX) عالية فى البط البكينى. بينما قياسات (HDL) ,(LDL) ,(MDA)زادت فى البط البغالى. وعند تقييم جودة اللحوم أظهرت قوة ألياف لحم الصدر والفخذ أقل قيمة فى البط المسكوفى. وجد أن جين النمو (GH)وجين (IGF-1) زاد فى البط البغالى عن السلالات الاخرى ولكن تعبير (Calpain) جين كان أعلى فى البط المسكوفى . نستنتج أن زيادة الصفات الإنتاجية فى البط البغالى ترجع إلىالاختلاففى التعبير الجينى للنمو ولكن جودة اللحوم الجيدة فى المسكوفى قد تعزى إلىإختلاف تعبير (Calpain).