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NUTRITIONAL IMPACT OF INORGANIC AND ORGANIC SELENIUM ADDITION IN MUSCOVY DUCK DIETS

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ABSTRACT

This work was intended to inspect the impacts of addition of different dietary selenium sources (Sodium selenite, selenium-enriched yeast, and seleno-methionine) on the growth parameters and carcass characteristics of Muscovy ducks. Also, hematological, serum biochemical parameters, immune status, antioxidant enzymes, gene expression, and economic efficiency were investigated. Forty-eight Muscovy ducklings (two weeks old) were randomly divided into four equal groups (12 ducklings/each). The 1st group (negative control) was given the basic diet without selenium addition, while sodium selenite was added to the diet in the 2nd group. The 3rd and 4th groups were induced by the basic diet with selenium-enriched yeast and seleno-methionine, respectively (0.4 mg selenium /kg diet). Results showed that ducks fed the basal diet, along with various forms of selenium, exhibited improved body weight gain and performance index. The 3rd and 4th groups displayed the highest values of the carcass traits, the relative weights of some internal organs, and muscle selenium content compared with the 2nd group (sodium selenite) and the negative control group. All selenium groups showed reduced levels of cholesterol, triglycerides, low density lipoprotein, and malondialdehyde (MDA) values, and there was a significant improvement in high density lipoprotein, red blood cell count, hemoglobin levels, white blood cell count, lymphocytes, neutrophils, immunoglobulin levels (IgA, IgM, IgG), and activity of superoxide dismutase (SOD) and glutathione peroxidase (GPX); also, both growth (*insulin-like growth factor*) and immune (*interleukin-10*) related genes were up-regulated. Conclusively, supplementation of organic selenium led to appreciable enhancements in all assessed parameters used in this study.

Keywords: Ducks, organic and inorganic selenium, antioxidant status, gene expression.

INTRODUCTION

Ducks rank as the second most prevalent poultry variety worldwide. Over the past few decades, the consumption of duck meat has surged due to its abundant nutrients, essential amino acids and ideal fatty acid composition abundant in polyunsaturated fatty acids with a harmonious balance between omega-6 and omega-3 (Pingel *and* Germany, 2011).

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Selenium is essential for optimal poultry performance as it is a vital micronutrient (Elnaggar *et al.,* 2020). It performs a crucial function in controlling various processes, including development, viability, meat characteristics, and protection against oxidative damage. More than thirty specific selenoproteins, such as the enzyme glutathione peroxidase, rely on selenium as an integral component (Zia *et al.,* 2017). Glutathione peroxidase (GPx) is an antioxidant enzyme that helps prevent the buildup of harmful free radicals (Oliveira *et al.,* 2014). Additionally, selenium is crucial in poultry diets to protect against pancreatic fibrosis and exudative diathesis. Hence, it's important to supplement poultry diets with selenium to establish a safety margin against deficiencies and to sustain peak levels of productivity (Göçmen *et al.,* 2016).

The Nutrient Requirements of Poultry (NRC ,1994) recommendations established the minimum selenium requirement for meat ducks at 0.20 milligrams of selenium per kilogram of the diet. In the animal industries, there is worry that this minimum recommendation is not adequate to prevent production losses from selenium deficiency syndromes, so research continues into alternative selenium sources and levels. The availability of selenium is influenced by the form in which it exists physically. Broiler diets typically include two basic forms, inorganic and organic, to meet the chickens' selenium requirement. Sodium selenite (Na_2SeO_3) and sodium selenate (Na_2SeO_4) have traditionally been widely utilized as sources of Se in broiler diet formulations. However, organic Se sources such as seleno-methionine ($C_5H_{11}NO_2Se$), selenocysteine ($C_3H_7NO_2Se$), and selenium-enriched yeast have become increasingly popular because of their improved absorption and prolonged presence in the tissues, compared to inorganic selenium (Kim and Kil, 2020). Studies on broilers have shown that incorporating 0.4 mg of organic Se (Se-yeast) per kilogram into their diet led to the most notable improvement in growth performance among ducks. Furthermore, the addition of selenium resulted in a notable rise in selenium concentrations in plasma, liver, and muscles, as well as enhancing the function of the glutathione peroxidase enzyme in plasma (Baltić *et al.,* 2015 and 2016). Sun *et al.* (2021) demonstrated that organic selenium was essential in improving the growth and immune system reaction of broiler chickens under conditions of high stocking density and heat stress. In another study, Khan *et al.* (2023) proposed that the addition of organic selenium to the diet of naked neck chicks could potentially improve their growth and slaughter characteristics without any negative effects on their blood chemistry.

Previous studies on mineral nutrition have mainly focused on macro-elements like calcium and phosphorous, with little focus on microelements such as Se in duck nutrition. Therefore, the purpose of this study was to investigate the impact of different dietary selenium sources (including inorganic *and* organic) on growth development parameters and carcass characteristics of ducks. Additionally, tissue Se distribution, hematological, serum biochemical parameters, antioxidant enzymes, immunological parameters, gene expression, and economic efficiency were studied.

MATERIALS AND METHODS

Approval for ethical considerations

The experiment was performed according to the standards of OIE for use of animals in research and in accordance with relevant guidelines and regulations approved by the Faculty of Veterinary Medicine at Assiut University with approval number (06/2024/0217).

Experimental birds and housing

The study was conducted at the Nutrition *and* Clinical Nutrition Research Unit located within the Teaching Veterinary Hospital at the Faculty of Veterinary Medicine at Assiut University. A total of 48 Muscovy ducklings (2 weeks old) were acquired from a local commercial source. The ducklings were divided into four equal groups, twelve each, in three replicates (four ducklings per group). The average initial weight of the experimental ducks was (314.1±7.3 g). All bird groups were housed in ground-level enclosures and kept under identical management and environmental circumstances.

Selenium additives:

Sodium selenite (inorganic Se, Na_2SeO_3)

Anhydrous sodium selenite was purchased from SRL Company, India, and added at 0.956 mg/kg to the diet.

Selenium-enriched yeast (organic selenium)

Se-enriched yeast (YeaSel plus 3000 ppm) was produced from Angel yeast (Egypt) Co., Ltd. YeaSel plus 3000 ppm is inactive dried organic Se yeast (*Saccharomyces cerevisiae*) containing 3000 mg Se/kg selenium enriched yeast. It is added to the basic diet at a level of 133 mg/kg to supply 0.4mg Se/kg of the diet.

Seleno-methionine (organic selenium)

A commercial seleno-methionine preparation "Selmix" waspurchased from Kenavet International Company, Mansoura, Egypt (Origin XVet, Germany). Each 1 kg of Selmix contains 1000 mg Se. It is added to the basic diet at a level of 400 mg/kg of the diet to supply 0.4 mg Se/kg of the diet.

Experimental diets *and* feeding

Ducklings were given feed based on a grower-finisher (15- 70 days) feeding program. The ducklings were divided into four categories: one control group and three experimental groups based on the type of selenium used. The basic control diet was prepared as a ground mixture (consisting of yellow corn, soybean meal, wheat bran, high- fat soybean meal, sunflower oil, and additional components) following the NRC's (1994) recommendations to meet the dietary requirements of growing ducks, except for selenium. The basic control diet contains a small quantity of selenium (0.12 mg/kg of the diet) present in feed ingredients. Samples of the formulated diet were taken and examined for dry matter, crude protein, ether extract, crude fiber, ash, and nitrogen-free extract using the Association of Official Analytical Chemists method(AOAC, 2011). The duck diets were provided in mash form. Ducks in the 1st group were fed *ad-libitum* on a basic control diet, with no added source of selenium. Ducks in the 2nd group were fed a basic control diet supplemented with 0.4 mg sodium selenite per kg of the diet (equivalent to 0.956 mg sodium selenite per kg of the diet),according toBaltić *et al.* (2015) and (2016). Ducks in the third and fourth groups received a basic control diet supplemented with Se-enriched yeast (YeaSel plus 3000 ppm (133 mg/kg) and seleno-methionine (Selmix (400 mg/kg), respectively. The composition of the basal diet in both physical and chemical terms is shown in Table (1).

Performance parameters

Weekly performance parameters, including live weight development and feed intake, were documented. Weight gain, ratio of feed consumed to weight gained, and performance index were all calculated during the entire trial period.

Table 1: The physical and calculated chemical composition of the basal diet.

Items	Basal diet
Physical composition (%)	
Ground yellow corn	65.17
Soybean meal	9.80
Wheat bran	10.00
Soybean meal (high fat 7%)	11.20
Sunflower oil	1.00
Mono-calcium phosphate	1.00
Limestone, ground	1.00
Common salt	0.30
Methionine	0.05
Lysine	0.05
Premix*	0.30
Choline chloride	0.03
Sodium bicarbonate	0.10
Calculated chemical composition (%)	
Dry matter	89.55
Crude protein	16.01
Ether extract	4.51
Crude fiber	3.44
Nitrogen free extract	62.61
Ash	2.98
Calcium	0.70
Available Phosphorus	0.34
Lysine	0.84
Methionine	0.31
Selenium**	0.12
ME (kcal/kg)***	3001

*Each 3 kg contains the following: Vit. A, 12000000 IU; Vit. D3, 4000000 IU; Vit. E, 50000 mg; Vit. k3, 3000 mg; Vit. B1, 3000 mg; Vit. B2, 7000mg; Vit. B6, 4000 mg; Vit. B12, 20 mg; Vit. B3, 50000 mg; Pantothenic acid, 15000 mg; Folic acid, 2000 mg; Biotin, 150 mg; Manganse, 100000 mg; Copper, 15000 mg; Iron, 30000 mg; Zinc, 80000 mg; Cobalt, 150 mg ; Iodine, 1250 mg; Betaine, 100000 mg (Universel Animal Care Company).

**Se content of the feed ingredients cited from NRC (1994).

***GE: estimated by bomb calorimeter and then metabolizable energy (ME) was calculated.

Carcass traits and meat Se estimation

After the end of the experimental period, three birds were selected randomly from all groups (one from each replicate), and their weights were recorded before being slaughtered after fasting overnight. The weights of the hot carcass, dressed carcass, and absolute weights of internal organs were all documented. We indicated the weights of the eviscerated, dressed, and internal organs as a proportion of the total live weight. To estimate tissue selenium, 0.1 g of duck muscles (breast and thigh) was placed in a digestion tube, followed by the addition of 8 mL of HNO3. The mixture was then processed in a microwave digestion system. After reducing some acidic components at 160°C using an electric heating plate to retain 1 mL of solution, deionized water was added to reach a total volume of 10 mL. The selenium concentration was measured according to the method outlined by Wahlen *et al.* (2005) using the Agilent 7500 series inductively coupled plasma-mass spectrometer from Agilent Technologies in Santa Clara, CA.

Blood sampling

At the end of the trial, six ducks were chosen at random from every group (two from each replicate) to have blood samples collected. Blood was drawn from the wing vein into tubes without heparin (three samples). The serum was separated by centrifugation and then stored at -18°C for later analysis. Serum samples were tested for total protein, albumin, triglycerides, cholesterol, LDL, HDL, and concentrations of immunoglobulin (IgA, IgM, and IgG) using a spectrophotometer with the commercial test kits (spectrum, Cairo, Egypt). Serum globulin was calculated as the difference between serum total protein and albumin. Additionally, three more blood samples were collected with EDTA as an anticoagulant for analysis of hematological parameters.

Antioxidant capacity

Liver samples were analyzed for glutathione peroxidase (GPX), superoxide dismutase (SOD) and malondialdehyde (MDA) concentrations. All enzymatic assays were conducted according to the manufacturer’s instructions using commercial biochemical reagent kits. The commercial kits used for measures of antioxidant status were purchased from Bio Diagnostic Company (Giza, Egypt).

Gene expression analysis

Expression of growth (*insulin-like growth factor*) and immune (*interleukin-10*) related genes was examined in the liver and spleen of three ducks from each experimental group. RNA extraction was performed from preserved liver and spleen tissues.1 microgram RNA sample went through an invert record with the H-short cDNA union unit according to the manufacturer's instructions. The cDNA was preserved at -20°C for later use. Primers for *β-actin*, *interleukin-10*, and *insulin-like development factor* were planned in view of quality bank data from the Public Place for Biotechnology Data (Bethesda, MD). PCR was performed as described by (Pfaffl *and* Hageleit, 2001).

Table 2: Primers used in the current examination.

Gene		Nucleotide sequence	Amplicon size (bp)	Accession number
Interleukin -10	F	AGA CGT TCA AGG AGA AGC	103	AJ621614
	R	TCC TCG AGG TAC AGC ATC		
Insulin-like factor	F	CA CAT CAC AGG GGC GGC	215	JN942579
	R	AAG TTC AAG AAA GGC CCC		
β-actin	F	TA TGG TGG GTC GCT AGT CAC CAA	205	X00182

Economical evaluation

The total cost of production was determined by factoring in the costs of 15-day-old ducklings, feeding, and management. The experimental diet's cost was established using the current market prices during the experiment, while the sales price was determined by multiplying the overall weight of the live ducks produced by the prevailing unit price in the market. Subsequently, the net revenue, economic feed efficiency, and corresponding relative economic feed efficiency were calculated.

Statistical analysis

The statistical software SPSS version 14 was used to analyze the recorded data, and differences from (P <0.05) were considered significant.

RESULTS

1-Growth performance parameters

Organic and inorganic selenium supplementation led to a notable increase in live weight and weight gain, compared to the control group, as indicated in Table 3. Ducks received either organic or inorganic selenium showed a notable improvement in the ratio of feed consumed to weight gained(FCR) and a significantly higher performance index (PI),compared to the control group. The most favorable FCR and PI were in the third group, which consumed a diet with Se-Yeast, followed by the 4th group, that consumed a diet with Se-Meth in contrast with the second group, which consumed a diet with sodium selenite and the control group.

2- Carcass traits and meat selenium content

Impact of Se source on the carcass characteristics and selenium levels in duck meat represented in Table 4. In the organic and inorganic selenium groups, there was a notable enhancement in the carcass trait parameters, the relative weights of certain internal organs, and tissue selenium content, compared to the control group, as the highest values were observed in the 3rd group followed by the fourth one

3- Biochemical markers in serum *and* enzymes that act as antioxidants

The total serum protein, albumin and globulin did not differ significantly (P>0.05) between the treated and control groups, as shown in Table 5. Addition of various dietary selenium sources led to a notable decrease in cholesterol levels, triglycerides, LDL, and MDA values and a notable rise in HDL, SOD, and GPX levels compared to the control.

3-Hematological parameters *and* immune status

Table 6 showed that the addition of various selenium forms to the diet of ducks led to a notable rise in the number of RBCs, HGB, WBCs, lymphocytes, neutrophils, and immunoglobulin values (IgA, IgM, IgG), compared to the control group.

4-Economical evaluation

Economic evaluation of ducks outlined in Table 7. Ducks that fed on diets supplemented with selenium (especially organic selenium) exhibited the best net revenue, economic fed efficiency (EFE), and relative economic feed efficiency (REFE) values compared to the control group. These results highlight the advantages of using different selenium sources (inorganic and organic Se) in the growing ducks.

5- Growth and immune related genes

All experimental groups (inorganic and organic Se), exhibited up regulation in the expression of both immune-related gene(*IL-10*) and growth-related gene(*IGF*),compared to the control group, as illustrated in figures 1 *and* 2. Ducks that fed on a diet containing Se-yeast exhibited a notable rise in the levels of *IL-10* and *IGF* in the spleen and liver, followed by birds supplemented with Se-Meth. and NaSe, respectively, compared to the control (without Se).

Table 3: Ducks' growth parameters throughout the entire experimental duration.

Groups** / Items	G1	G2	G3	G4
Initial body weight (g/duck)	314.1±7.3	320.6±8.6	355.0±9.3	315.7±8.9
Final body weight (g/duck)	3220.3±67.4^{c*}	3472.3±90.5^{b}	3608.9±77.4^{a}	3585.4±88.8^{ab}
Total weight gain (g/duck)	٢٩٠٦,٢±142.4^{c}	٣١٥١,٧±184.6^{b}	٣٢٥٣,٩±198.9^{a}	٣٢٦٩,٧±183.2^{ab}
Total feed intake (g)	10018.6±291.5^{a}	9976.3±286.6^{ab}	٩٧٢٩,٢±279.4^{b}	9884.1±282.3^{b}
FCR(Feed-to-gain ratio)	3.45±0.15^{a}	3.17±0.16^{ab}	2.99±0.16^{b}	3.02±0.16^{ab}
Performance index (%)	93.34±11.36^{c}	109.54±23.51^{b}	12٠.70±18.67^{a}	118.72±21.59^{ab}

*Means within the same row with different superscripts are significantly different (P < 0.05).
**G1: Control (without Se), C2: Control + Inorganic Se (NaSe),
G3: Control + Organic Se (Se yeast), G4: Control + Organic Se (Se Meth.).

Table 4: Carcass traits and meat selenium content in the muscles of ducks fed different experimental diets.

Groups / Items	G1	G2	G3	G4
Preslaughter wt. (g)	2992±64.4^{c}	3283.7±89.9^{bc}	3587±66.7^{a}	3343.3±78.2^{b}
Hot carcass wt. (g)	2455±68.8^{b}	2769.3±36.1^{a}	2796.3±63.4^{a}	2778.7±52.3^{a}
Eviscerated wt. (g)	2074±67.9^{c}	2377±55.3^{bc}	2662±45.5^{a}	2461.7±57.7^{b}
Eviscerated (%)	69.٣±2.4^{b}	72.4±4.2^{a}	74.2±4.5^{a}	73.6±3.3^{a}
Dressing wt (g)	2185.7±37.7^{c}	2486.3±31.4^{bc}	2800.3±46.3^{a}	2586.3±36.6^{b}
Dressing (%)	73.1±1.8^{b}	75.7±1.5^{ab}	78.1±1.6^{a}	77.4±1.2^{ab}
Heart (%)	0.49±0.07	0.53±0.04	0.60±0.14	0.57±0.09
Liver (%)	0.84±0.03^{c}	0.93±0.09^{bc}	1.12±0.24^{b}	1.09±0.17^{b}
Gizzard (%)	1.35±0.33^{b}	1.47±0.45^{ab}	1.80±0.47^{a}	1.56±0.51^{ab}
Spleen (%)	0.05±0.01	0.06±0.01	0.08±0.02	0.07±0.01
Se content in muscles (mg/kg dry weight)	1.318±0.5^{c}	2.391±0.5^{b}	4.103±0.6^{a}	3.058±0.6^{ab}

*Means within the same row with different superscripts are significantly different (P < 0.05).

Table 5: Biochemical components *and* antioxidant enzymes of ducks.

Groups / Items	G1	G2	G3	G4
Total Protein (g/dl)	3.11±0.10	3.19±0.07	3.18±0.10	3.17±0.12
Albumin (g/dl)	1.28±0.03	1.25±0.03	1.30±0.06	1.24±0.03
Globulin (g/dl)	1.83±0.09	1.94±0.09	1.88±0.07	1.93±0.09
Cholesterol (mg/dl)	$169±11.58^{a}$	$158±14.19^{ab}$	$146.33±14.62^{b}$	$156.33±13.57^{ab}$
Triglycerides (mg/dl)	$93.00±14.53^{a}$	$86.00±24.00^{ab}$	$66.67±11.29^{c}$	$73.33±22.04^{b}$
HDL (mg/dl)	$37.67±6.17^{b}$	$50.67±2.96^{a}$	$57.67±4.41^{a}$	$57.33±3.18^{a}$
LDL (mg/dl)	$80.97±10.73^{a}$	$79.21±8.87^{ab}$	$74.30±4.27^{ab}$	$78.33±8.20^{ab}$
MDA nmol/g	$9.60±0.64^{a}$	$8.80±0.17^{ab}$	$7.57±0.61^{b}$	$8.27±1.47^{ab}$
SOD (U/g)	$20.07±0.15^{b}$	$24.27±0.09^{ab}$	$26.27±0.20^{a}$	$25.80±0.54^{ab}$
GPX (U/g)	$42.17±15.63^{d}$	$51.87±18.74^{c}$	$155.60±18.71^{a}$	$73.80±13.06^{b}$

*Means within the same row with different superscripts are significantly different (P < 0.05).
HDL = High density lipoprotein, LDL = Low density lipoprotein, MDA = malondialdehyde, SOD = superoxide dismutase, and GPX = glutathione peroxidase.

Table 6: Hematological metrics and immune status of ducks.

Groups / Items	G1	G2	G3	G4
RBCs (x10^{6}/µl)	$2.17±0.09^{b}$	$2.93±0.10^{ab}$	$3.56±0.12^{a}$	$3.27±0.06^{a}$
HGB (g/dl)	$9.60±0.32^{b}$	$13.06±0.64^{ab}$	$14.07±0.49^{a}$	$13.67±0.31^{ab}$
WBCs (x10^{3}/µl)	$84.00±2.08^{b}$	$90.13±2.07^{a}$	$90.97±4.51^{a}$	$90.43±3.52^{a}$
Lymphocytes (%)	$78.33±2.33^{b}$	$82.17±1.15^{a}$	$82.83±1.20^{a}$	$82.46±2.52^{a}$
Neutrophils (%)	$9.67±0.33^{b}$	$11.08±0.33^{a}$	$11.19±1.00^{a}$	$11.23±1.53^{a}$
IgA (mg/dl)	$2.66±0.01^{b}$	$4.51±0.76^{ab}$	$5.13±0.05^{a}$	$4.89±0.26^{ab}$
IgM (mg/dl)	$0.88±0.41^{b}$	$2.24±0.69^{a}$	$2.62±0.86^{a}$	$2.54±0.53^{a}$
IgG (mg/dl)	$41.50±0.69^{b}$	$43.50±0.92^{ab}$	$45.95±2.45^{a}$	$45.60±0.52^{a}$

*Means within the same row with different superscripts are significantly different (P < 0.05).
RBCs = Red blood cells, HGB = Hemoglobin, WBCs = White blood cells, IgA = Immunoglobulin A, IgM = Immunoglobulin M, and IgG = Immunoglobulin G.

Table 7: Economical assessment of the experimental diet fed to ducks.

Groups / Items	G1	G2	G3	G4
Price/kg feed (L.E)	8.742	8.744	8.765	8.822
Total feed cost (L.E)	87.58	87.23	86.18	87.20
Total production cost (L.E)	142.58	142.23	141.18	142.20
Price/kg body weight (L.E)	50.00	50.00	50.00	50.00
Price/duck or Total revenue (L.E)	161.02	173.62	180.45	179.27
Net revenue (L.E)	18.42	31.39	39.27	37.07
Economical feed efficiency (%)	12.92	22.07	27.82	26.07
Relative economic feed efficiency	100.00	170.82	215.33	201.78

L.E = Egyptian pound.

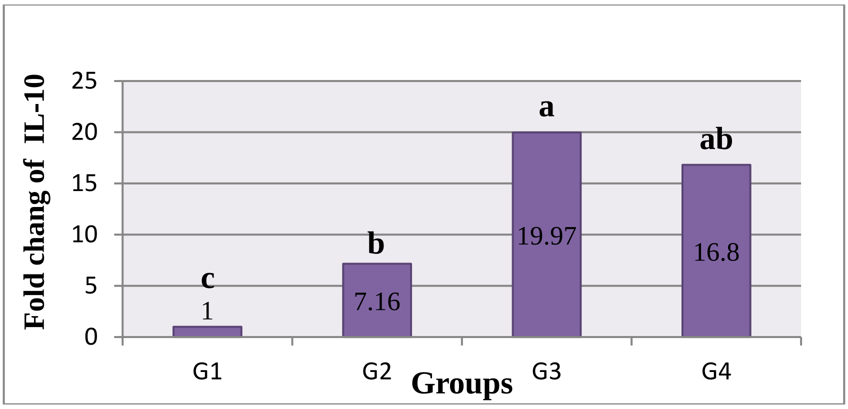

Figure1: Expression of immune related gene in ducks' spleen.

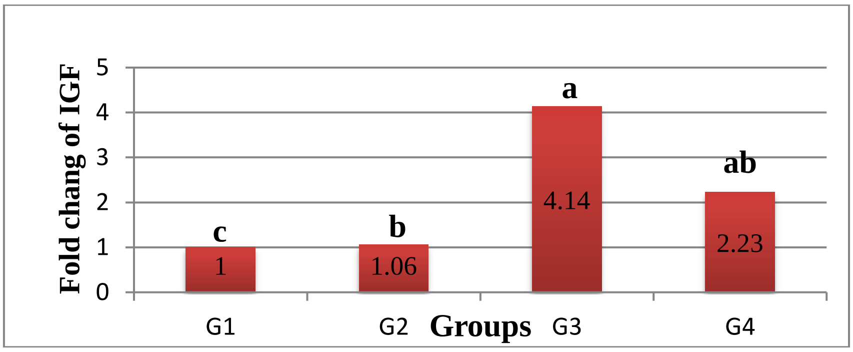

Figure 2: Expression of the growth-related gene in ducks' liver.

DISCUSSION

1-Growth performance

Since selenium is known to be an essential component of the iodothyronine deiodinase enzyme, its involvement in the metabolism of the body and growth may be linked to its beneficial effect on the weight of birds in the treated groups (Zhang *et al.*, 2011). The Iodothyronine deiodinase enzyme is responsible for transforming the prohormone thyroxin into triiodothyronine (active hormone), which is necessary for birds to grow and develop normally (Chun *et al.*, 2009; Ankur *and* Baghel, 2011). Furthermore, T3 is a crucial growth regulator, as it controls the energy of body and protein metabolism (Preter, 2000). The results obtained agree with the research findings conducted by Baltić *et al.* (2016), which concluded that incorporating 0.4 mg of organic selenium per kilogram in the diet resulted in the best growth performance for ducks. Studies conducted on broilers also demonstrated that adding organic selenium to their diets at concentrations of 0.45 and 0.6 mg/kg led to a notable increase in live weight and weight gain, as well as an enhanced FCR, compared to broilers fed with the same amount of inorganic selenium and control (Ibrahim *et al.*, 2019; Elnaggar *et al.*, 2020; Arnaut *et al.*, 2021; and Khan *et al.*, 2023). This enhancement may be attributed to the superior availability of organic selenium compared to inorganic selenium (Edens *et al.*, 2001), leading to an increase in live weight. Conversely, some studies reported that addition of selenium in the diet of broilers had no significant impact on the growth-related performance (Wang *et al.*, 2011; Ahmad *et al.*, 2012; Chen *et al.*, 2013; Rao *et al.*, 2013; Li *et al.*, 2017; and Bakhshalinejad *et al.*, 2019). The discrepancies in the results may be attributed to variations in species, age of the birds, duration of the experiment, and the amount of Se included in the diet.

2- Carcass traits and tissue selenium distribution

The carcass characteristics and selenium content in tissues showed similar results to the study conducted by Baltic *et al.* (2015), who observed that ducks fed a diet supplemented with 0.2 and 0.4 mg of selenium yeast displayed increased cold carcass weight and dressing, compared to ducks fed a control basal diet devoid of selenium. Similarly, Marković*et al.* (2018) and Khan *et al.* (2023) demonstrated that broilers supplemented with Se yeast had higher carcass weights and dressing percentages than the control. The higher live weight and gain in the selenium-supplemented groups compared to control may be the cause of improved carcass trait values in growing ducks. It is known that giving birds selenium as a growth promoter makes them grow faster by making it easier for the gut to absorb nutrients, which has a direct impact on carcass trait parameters (Krstić *et al.*, 2012; Elnaggar *et al.*, 2020). On the other hand, Liu *et al.* (2023) found that the majority of the carcass characteristics of broilers in the groups supplemented with Se-yeast and the control group were identical.

The tissue selenium distribution data aligned with the results of Baltic *et al.* (2015), who indicated that addition of organic selenium to the diet significantly increased selenium levels in duck meat, compared to control. Likewise, Ibrahim*et al.* (2019); Deng *et al.* (2022); An *et al.* (2023); Khan *et al.* (2023) and Wickramasuriya *et al.* (2023), who observed a notable increase in selenium deposition in broiler breast muscles when supplemented with Se-methionine or Se-yeast, as opposed to the control group. Addition of selenium to the diet of ducks resulted in an improvement in live weight and carcass traits, and this was also apparent in the distribution of selenium within their tissues. Furthermore, ducks fed on diets supplemented with 0.40 mg selenium/kg showed the highest selenium levels in their breast and thigh muscles compared to control, with organic Se being retained to a greater extent in chicken muscle tissue than inorganic selenium. This difference may be related to variations in bioavailability and metabolic utilization pathways between Se sources, as reported by Krstić *et al.* (2012). Conversely, Ahmad *et al.* (2012) and Giamouri *et al.* (2021) illustrated that selenium contents of chicken breast meats did not show any notable variances between the control group and the sodium selenite group.

3-Serum biochemical parameters *and* antioxidant enzymes

Supplementation of various Se sources did not show any significant impact on the serum total protein, albumin and globulin. These findings coincide with Zhang*et al.*(2020), who found that dietary Se-yeast inclusion at different levels did not show any noticeable impact on the serum total protein, albumin, and globulin of laying ducks. Alian *et al.* (2020) and Eid *et al.* (2022) also found that broilers diet containing various sources of selenium did not significantly alter serum total protein or albumin levels. Conversely, Eid *et al.* (2023) and Khan *et al.* (2023) noted a rise in serum total protein, albumin, and globulin levels in chickens that received organic or inorganic Se compared to non-treated chickens (control). Inclusion of both inorganic and organic selenium in the diet of ducks resulted in a reduction in serum cholesterol, triglycerides, and LDL, with a notable increase in HDL level, compared to control. The results of Elnaggar *et al.* (2020) agree with these findings, as they noted comparable effects in broilers given diets containing both organic and inorganic selenium at a concentration of 100 ppm/kg. Ibrahim *et al.* (2022) demonstrated that turkeys fed diets containing different selenium sources (Sel-Plex, Na-selenite, and nano-Se at 0.41, 0.42, and 0.43 mg/kg, respectively) had lower concentrations of cholesterol, triglycerides, LDL, and total lipids compared to those fed on a selenium-free control diet. Conversely, Khan *et al.* (2023) found that naked neck chickens fed on a diet containing organic selenium (0.3

ppm/kg) did not show any significant effects on serum cholesterol and triglyceride levels.

The impact of selenium sources on antioxidant enzymes is consistent with the results of Baltić *et al.* (2015), who demonstrated that ducks fed a diet supplemented with selenium showed a significant increase in plasma GSH-Px activity, compared to the control group. Additionally, Li *et al.* (2017); Prasoon *et al.* (2018); Arnaut *et al.* (2021) and Deng *et al.* (2022)reported that incorporating organic and inorganic Se into the diet resulted in a notable increase in GPX and SOD enzyme activity, along with a reduction in MDA concentration in broilers. Conversely, Chen *et al.* (2014) and Chen *et al.* (2015) discovered that adding inorganic and organic Se to broiler diets did not result in a notable impact on T-SOD activity.

3-Hematological picture and immune status

In all Se groups, there was a notable rise in HDL, RBC count, hemoglobin, WBCs, lymphocytes, and neutrophils, compared to the control group. This finding aligns with the results of Elnaggar *et al.* (2020),as they observed a rise in RBCs and hemoglobin in broilers given diets containing both organic and inorganic selenium at a concentration of 100 ppm/kg. Conversely, Chen *et al.* (2014)found that inclusion of various selenium sources (selenite Se and yeast Se) at concentrations of 0.41 and 0.43 mg Se per kilogram of the diet did not show any notable impact on the levels of WBCs, RBCs, and HGB in broiler blood. Also, Woods *et al.* (2020)stated that broilers consuming diets with selenized yeast and Na-selenite had the lowest hemoglobin concentration, while those fed the control diet (without Se) had the highest hemoglobin concentration. Further-more, An *et al.* (2023)recorded that WBC, RBC, and lymphocyte levels were not significantly impacted by Se-Met (0.2 *and* 0.4 ppm/kg diet) supplementation in broiler diets.

The effect of selenium sources on immune function was in accordance with the results of Dalia *et al.* (2020), who indicated that adding either inorganic or organic selenium to broiler diets at a concentration of 0.3 mg/kg notably increased serum immunoglobulin levels (IgA, IgM, and IgG), compared to the control group. However, Chen *et al.* (2014) and Chen *et al.* (2015)observed that adding sodium selenite and selenium yeast to the diet of broilers at concentrations of 0.41 and 0.43 mg per kilogram did not have a significant impact on serum immunoglobulin levels.

4- Gene expression

Results of gene expression were in the same line with the findings of Saleh and Ebeid (2019), who showed that the mRNA levels of *IGF-I* were notably elevated when broilers' diet supplemented with nano-Se (0.5 mg/kg).

5-Economical evaluation

The findings on the impact of Se sources on economic values of ducks were agree with the results reported by Eid *et al.* (2022), who observed a reduction in the total feed cost decreased for chicks fed SeNPs and Sel-Plex diets (at level 0.3 mg/kg) due to reduced feed intake, while the selling price increased due to an increase in average weight gain (kg/head).Additionally, the net revenue was higher in chicks fed SeNPs and Sel-Plex diets.

CONCLUSION

Growth parameters, carcass characteristics, blood metrics, immunity, antioxidant capacity, gene expression, and economic efficiency of growing ducks were enhanced by dietary supplementation with various selenium sources (inorganic and organic Se). Ducks that consumed diets supplemented with organic Se exhibited superior results compared to those fed on inorganic selenium.

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الأثر الغذائي لإضافة السيلنيوم الغير العضوي والعضوي في علائق البط المسكوفي

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أجريت هذه الدراسة الحالية لتقييم تأثير إضافة مصادر مختلفة من السيلنيوم الغير العضوي (سيلينيت الصوديوم) والعضوي (السيلنيوم المحمل على الخميرة و السيلنيوم المحمل على الميثيونين) في علائق البط على كفاءة الأداء الإنتاجي وصفات الذبيحة والقياسات البيوكيميائية الدموية والمصلية، والحالة المناعية ونشاط إنزيمات الأكسدة والتعبير الجيني والكفاءة الاقتصادية. تم توزيع عدد ٤٨ من صغار البط المسكوفي (عمر أسبوعين) عشوائياً إلى ٤ مجموعات متساوية، (اثني عشر بطةً لكل مجموعة) في ثلاث مكررات (٤ بطات لكل مكرر). المجموعة الأولى (الضابطة) غذيت على العليقة الأساسية دون إضافة أي مصدر للسيلنيوم، بينما المجموعة الثانية غذيت على العليقة الأساسية مع إضافة سيلينيت الصوديوم بينما تغذت المجموعتين الثالثة والرابعة على العليقة الأساسية الضابطة مع إضافة السيلنيوم المحمل على الخميرة و السيلنيوم المحمل على الميثيونين، على التوالي لتوفير ٠,٤ ملجم من السيلنيوم / كجم من العلف.

أظهرت النتائج أن البط الذي تغذى على النظام الغذائي الأساسي مع أشكال مختلفة من السيلنيوم أظهر تحسنًا في زيادة وزن الجسم ومؤشر الأداء. أظهرت المجموعتان الثالثة والرابعة أعلى القيم لصفات الذبيحة والأوزان النسبية لبعض الأعضاء الداخلية ومحتوى السيلنيوم العضلي مقارنة بالمجموعة الثانية (سيلينيت الصوديوم) والمجموعة الضابطة السلبية. أظهرت جميع مجموعات السيلنيوم انخفاض مستويات الكوليسترول والدهون الثلاثية والبروتين الدهني منخفض الكثافة والمالونديالدهيد (MDA)، وكان هناك تحسن كبير في البروتين الدهني عالي الكثافة وعدد خلايا الدم الحمراء ومستويات الهيموجلوبين وعدد خلايا الدم البيضاء والخلايا الليمفاوية والمعدلات ومستويات الغلوبولين المناعي (IgA، IgM، IgG)، ونشاط إنزيمات المضادة للأكسدة الديسميوتيز (SOD) والجلوتاثيون بيروكسيداز (GPX)؛ أيضًا، تم تنظيم كل من الجينات المرتبطة بالنمو (عامل النمو الشبيه بالأنسولين) والمناعة (إنترلوكين -١٠).بشكل قاطع، أدت مكملات السيلنيوم العضوية إلى تحسينات ملحوظة في جميع المعايير المقدرة المستخدمة في هذه الدراسة.