Research Article

Organic Selenium Supplementation: A Convenient Approach to Improve Behaviour, Performance, and Economics and to Suppress Stress in Home-Cage Reared Ducks

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Abstract | Capturing of ducks at cages increased discomfort and stress. Herein, we tried to overcome this problem by addition of selenium in diet. We assessed the impact of organic selenium (0.4 gm/kg ration) supplementation on duck behaviour, welfare, thyroid hormones, and economic values. Forty-eight black Muscovy ducklings 3 weeks old, were reared in cage system and divided into two equal groups (control and Se-treated groups). No impact of the organic selenium supplementation on the feeding time, although the time was increased in the 10th week. The drinking bouts were significantly decreased ($p < 0.05$) in organic selenium treated group when compared with control group at finishing phase. The body weights ($p < 0.01$ in the 7th week, $p < 0.001$ in 8th, 9th and 10th weeks) and weight gains ($p < 0.01$ in 7th and 8th weeks) in the Se-treated group have been increased significantly compared to the control. Besides, the feed conversion ratio was highly decreased and relative growth rate was highly improved with organic selenium supplementation at both growing and finishing periods. Furthermore, the addition of organic selenium in caged ducks diet decreased the level of free thyroxine. On the economic basis, duck ration supplementation with organic selenium revealed the lowest cost/ kg weight gain, the highest economic return, net profit, and profitability index. Adding organic selenium to ration is important to display the duck's fundamental needs and behavioural patterns, and to ensure their welfare, productivity and economic gain.

Keywords | Behaviour, Duckling, Organic selenium, Thyroxine, Cage, Economic

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INTRODUCTION

The modern production of duck's meat is considered a beneficial industry, and therefore the housing/ rearing condition is one of the ducks' fundamental needs to improve their behavior and productivities. For instance, duck group managed in battery spent more day period in resting, walked less frequently, and for a shorter time than those floor housed duck (Carrière et al., 2006). However, capturing of ducks at cage/ battery increased their discomfort and stress. Meanwhile, feeding birds on dietary antioxidants has the ability to enhance their antioxidant status, health, and subsequent welfare (Woods et al., 2020). Hence, the behavior is an indicator of well-being of animals to assess the welfare, production, and economy (Wegner, 1992) we tried to overcome this captivity challenge by addition of selenium in diet. As well, selenium is an important antioxidant, used in the regulation of most metabolic processes, including antioxidant immune status and the metabolism process of thyroid hormone (Brown and Arthur, 2001). Furthermore, nutrition is a first concern of the poultry industry since it is compromises about 60-70 % of total cost of poultry production (Behnke and Beyer, 2004). Thus, the functional feeding is essential to assess the economic profits. The bird's health is a vital part of their life as the level of physiological comfort and welfare were reflected in their behavioural patterns, growth curve and feed utilization (Platz et al., 2003). Muscovy ducks, chosen in our study, are native to tropical South America and Central America, which are good at flying but do not like swimming (Abd El-Azeem, 2002). The origin of Muscovy duck is different from that of domestic duck, and both have great differences in living habits and feeding methods (Ling et al., 2018; Zenunovic and Glavic, 2018). Therefore, we tried to emphasize the influences of organic selenium supplementation on Muscovy ducks' behaviour, performance, economics, and suppressing stress in their home-cages.

MATERIALS AND METHODS

This research was performed at the research farm that belongs to Faculty of Veterinary Medicine, Zagazig University. The research protocol was approved by the Institutional 86 Animal Care 87 and Use Committee and Zagazig University (Approval No. ZU–IACUC/2/F/45/2020). The graphical presentation of experimental design of the study has been presented in Figure 1.

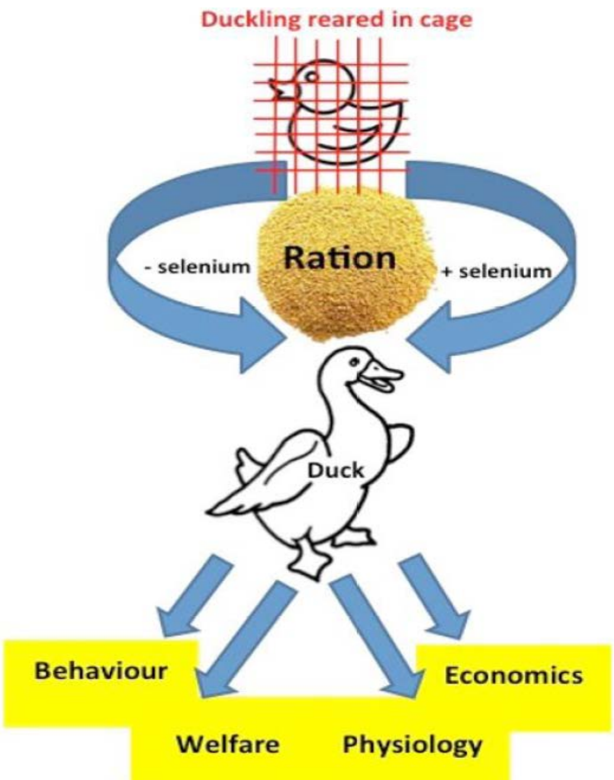

Figure 1: Experimental design of the work.

Birds used and management

Forty-eight black Muscovy ducklings, 3 weeks old, (350 g ± 20.1), were reared in cage system, with stocking density 8 birds/cage (Liste et al., 2013); feed and water were provided *ad-libitum*. Ducklings were classified into control and Se-treated group (three cages for each group). As shown in Table 1, control group was provided with commercial starter diet contained 22% crude protein until 5 weeks old. Then, it was fed a finisher diet with 18% of crude protein until week-10 (AOAC, 2002). The control group was fed a basal diet of in organic selenium in vit. premix (vitamin AD_3E, folic acid, biotin and in organic selenium 0.5%). Se-treated group was provided with 0.4 g organic selenium (Se yeast, as Sel-Plex, Alltech Inc. USA.)/kg ration on a daily basis (Zenunovic and Glavic, 2018).

Table 1: The composition of the basal control starter and finisher diet of Muscovy duck.

Ingredients	Starter	Finisher
Yellow corn	54%	65%
Soybean	40%	28.95%
Vegetable oil	3%	3%
Limestone	1%	1%
Dicalciumphosphate	1%	1%
Dl– Methionine	0.1%	0.1%
Salt	0.45%	0.45%
Vit.–Min. Premix1	0.5%	0.5%
Total (%)	100	100
Crude protien (%)	22%	18%
metabolized energy (kcal/kg)	3015	3125

Observation technique

A focal sample observation was used. Photographing digital camera (Hikvision, Binjiang District, Hangzhou, China) was used for recording the behavioural pattern 3-hour/ week for each treatment according to (Shimmura et al., 2007).

The behavioural analyses

The behavioural patterns were observed according to Chapuis et al. (2017), (i) ingestive behaviour, birds were fed from feeders or drinking, the mean time (second) were record, (ii) standing behaviour, ducks were standing idle and not engaged in any activity, (ii) walking behaviour, (iv) resting behaviour, birds sitting on ground, (v) comfort behavior, (feather preening), and (vi) aggressive pecking behaviour as the bird only pecked at the feathered parts of conspecifics.

Welfare assessments

Eyes quality, feather quality, footpad quality, and gait score of ducks were assessed and scale of 0 ~ 2, where 0 was the ideal and a 1 or 2 was a worst. The individual traits scores were scored on a scale of 0 ~ 1 (nostril and feather cleanliness). These welfare scores were detected previously according to Karcher et al. (2013).

Live duck performance

(i) live body weights were weakly record for each duck (ii) weight gain = w2-w1; (iii) relative growth, RGR% = $0.5 \times w2\text{-}w1/(w2+w1)$, (iv) feed intake that was estimated for each bird in and (v) feed conversion ratio = *weight gain/ feed intake*.

Stress hormones analysis

Blood samples were collected randomly from wing vein of eight birds per each group for evaluating thyroid stimulating hormones and free thyroxin (Mohammed et al., 2015).

Economic analysis

The economic values and profitability ratios were calculated in the 10th week according to the prevailing market price of ingredients and the body weight.

Economic values

The formulas were used according (Omar et al., 2019), for calculation of economic values; the feed costs (average variable costs)= total feed intake per bird × cost of one kg diet; A total costs (TC)= total feed cost + average fixed costs; the total revenue (TR)= live body weight × price/kg; the net profit (NP) = total revenue − total costs. The feed cost/kg weight gain = cost of feed consumed/ weight gain was estimated (Embaye et al., 2018).

Profitability ratio

The formulas were used according (Nworgu, 2007) for calculation of economic values; benefit cost ratio (BCR) = TR/TC; profitability index = NP/TR; gross ratio (GR) = TC/TR.

Statistical analysis

Statistical analysis was done using statistical system *SPSS*-version 16 and was performed using *t*-test to demonstrate the comparison between two groups, control and organic selenium supplementation groups). The comparison of average was analyzed using *Duncan's* multiple-range tests. *p* values < 0.05 for all mean effects showed significance. The *F* distribution has two parameters, the between-groups degrees of freedom, *k*, and the residual degrees of freedom, $N-k$, represented as the following formula: ($df1 = k-1$, $df2 = N-k$), where df, degree of freedom; *k*, number of groups; *N*, number of observations.

RESULTS AND DISCUSSION

The impact of selenium addition on the behavioural patterns of Muscovey ducks

Our obtained results in Table 2 showed that the feeding time had not been affected with organic selenium supplementation although there was a non-significant increase in the 10th week (976,67±153.69 in control, vs 1273.33±175.25 in selenium treatment group). Herein, the drinking duration time (second) of ducks in control group increased significantly, (p=0.017, $F_{(1,46)}$=63.023, at week-9). Moreover, the resting duration time (second) of ducks in selenium treated group has been increased significantly, (P=0.044, $F_{(1,46)}$=4.268; P=0.008, $F_{(1,46)}$=165.342; and P=0.004, $F_{(1,46)}$=128.572, at week-5, week-9, and week-10, respectively) compared to the controls. As a result shown in Table 3 referred to the feeding frequencies (bout) of ducks in selenium-treated group increased significantly, at week-7 and week-8 (P=0.034, $F_{(1,46)}$=1.937 and P=0.019, $F_{(1,46)}$=27.488, respectively) compared to the controls. Moreover, the drinking frequency (bout) of ducks in control group increased significantly, (p=0.005, $F_{(1,46)}$=0.000; and p=0.021, $F_{(1,46)}$=46.000, at week-9 and week-10, respectively) compared to the selenium-treated one. Also, the walking frequency (bout) of ducks in selenium-treated group has been increased significantly, (p=0.031, $F_{(1,46)}$=7.830, at week-7) compared to the control one. Furthermore, the preening frequencies (bout) of ducks in selenium-treated group has been increased significantly, (P=0.011 each, $F_{(1,46)}$=345, $F_{(1,46)}$=0.371, at week-8, and week-9, respectively) compared to the controls.

The impact of selenium addition on the welfare assessments of Muscovey ducks

The score of welfare assessments in Figure 2 ranged from 0 ~ 2, where 0 was the best or ideal condition while a 1 or 2 indicated the worse condition for that specific quality of ducks. Herein, our results showed that selenium improved the scores of food-pad, gait, feather quality; eye clean, nostril clean, and feather clean compared to those control ducks fed a basal diet. Importantly, these mentioned scores were the best significantly (p= 0.002, $F_{(1,46)}$=7.024; p=0.032, $F_{(1,46)}$=4.404; p=0.000, $F_{(1,46)}$=15.606; p=0.001, $F_{(1,46)}$=34.938; p=0.000, $F_{(1,46)}$=33.920; p=0.004, $F_{(1,46)}$=29.571) in the selenium-treated group in comparison with the control.

The impact of selenium addition on the performance of Muscovey ducks

As a result shown in Table 4, the body weight (g) showed that the weight of ducks in selenium treatment group has been improved significantly, (p=0.002, $F_{(1,46)}$=1.527; p=0.000, $F_{(1,46)}$=1.25; p=0.000, $F_{(1,46)}$=0.11; and p=0.000, $F_{(1,46)}$=0.841, in week-7, week-8, week-9, and week-10, respectively) compared to the controls. As well, the weight gain (g)

Table 2: The behavioural duration (second) of control and selenium supplemented diet groups of Muscovy duck, from week-4 until week-10 of age.

Week	Group	Behavioural duration (second)				
		Feeding-time	Drinking-time	Standing-time	Walking-time	Sitting-time
Week-4	CNT	716,67 ± 208.83	648,33 ± 111.59	116,67 ± 32.83	96,67 ± 21.86	2701,00 ± 132.48
	Se-treated	836,67 ± 37.23	857,33 ± 113.62	110,33 ± 34.35	99 ± 27.21	2706,00 ± 161.06
Week-5	CNT	624,33 ± 239.81	667,33 ± 294.73	53,00 ± 14.80	15,67 ± 3.84	2161,00 ± 73.51
	Se-treated	769,00 ± 215.13	812,33 ± 123.85	46,67 ± 9.82	7,67 ± 1.86	2924,00 ± 251.41*
Week-6	CNT	720,00 ± 231.80	762,00 ± 253.02	125,00 ± 38.19	14,33 ± 1.20	1190,00 ± 121.24
	Se-treated	781,33 ± 247.28	700,00 ± 205.26	117,00 ± 28.71	11,00 ± 1.15	1842,67 ± 298.55
Week-7	CNT	703,33 ± 276.55	270,00 ± 81.85	110,00 ± 10.00	12,00 ± 5.039	1916,67 ± 365.53
	Se-treated	1004,67 ± 61.86	252,67 ± 56.57	125,00 ± 11.59	8,67 ± 1.76	2148,00 ± 43.10
Week-8	CNT	808,00 ± 233.21	551,33 ± 142.65	68,67 ± 48.18	10,33 ± 3.28	1125,00 ± 186.89
	Se-treated	964,67 ± 309.46	495,67 ± 138.65	14,67 ± 1.20	10,67 ± 2.60	1485,33 ± 495.37
Week-9	CNT	964,33 ± 86.19	1853,00 ± 349.74*	125,00 ± 50.50	6,67 ± 4.67	737,67 ± 212.28
	Se-treated	964,33 ± 96.76	455,67 ± 68.63	19,00 ± 2.65	9,33 ± 2.03	2086,33 ± 167.71**
Week-10	CNT	976,67 ± 153.69	993,67 ± 121.49	125,00 ± 50.50	6,67 ± 4.67	737,67 ± 212.28
	Se-treated	1273,33 ± 175.25	760,33 ± 154.12	57,00 ± 7.81	7,00 ± 2.52	2201,67 ± 111.24**

The result was presented as mean ± SEM and analyzed using t-test, SPSS-version 16. CNT, control; se-treated, selenium-treated; (*), P ≤ 0.05; (**), P ≤ 0.01.

Table 3: The behavioural frequencies (bout) of control and selenium supplemented diet groups of Muscovy duck, from week-4 until week-10 of age.

Week	Group	Behavioural frequencies (bout)						
		Feeding frequency	Drinking frequency	Standing frequency	Walking frequency	Sitting frequency	Preen frequency	Aggression frequency
Week-4	CNT	6.33 ± 0.88	16.33 ± 2.03	6.33 ± 1.86	25.67 ± 7.45	18.00 ± 2.31	14.33 ± 0.88	0.67 ± 0.33
	Se-treated	6.33 ± 2.33	16.33 ± 3.53	7.00 ± 2.31	36.00 ± 7.45	12.67 ± 1.2	14.67 ± 2.03	0.33 ± 0.33
Week-5	CNT	7.00 ± 3.00	11.33 ± 3.76	2.33 ± 0.33	8.33 ± 3.71	17.67 ± 3.76	11.33 ± 3.38	2.33 ± 0.33
	Se-treated	11.33 ± 3.48	10.33 ± 2.4	4.33 ± 0.88	8.67 ± 3.76	23.00 ± 4.73	15.00 ± 3.61	1.00 ± 0.58
Week-6	CNT	5.67 ± 0.33	11.33 ± 2.33	3.00 ± 0.58	6.33 ± 0.88	16.00 ± 2.65	11.00 ± 3.21	2.00 ± 0.58
	Se-treated	8.33 ± 1.86	11.67 ± 0.88	5.33 ± 1.45	6.33 ± 1.45	19.67 ± 1.2	18.00 ± 1.15	0.67 ± 0.33
Week-7	CNT	5.67 ± 1.76	9.00 ± 2.89	3.67 ± 0.889	4.00 ± 1.73	15.67 ± 4.98	16.33 ± 2.73	0.67 ± 0.33
	Se-treated	12.33 ± 1.45*	10.33 ± 1.21	6.00 ± 1.53	10.33 ± 0.88*	17.67 ± 1.67	20.00 ± 4.36	0.33 ± 0.33
Week-8	CNT	5.33 ± 0.33	9.00 ± 1.53	3.00 ± 0.58	4.67 ± 2.03	14.00 ± 4.51	11.33 ± 1.67	0.33 ± 0.33
	Se-treated	12.00 ± 1.73*	10.00 ± 1.15	4.34 ± 0.88	7.33 ± 0.88	13.33 ± 3.53	22.33 ± 1.76*	0.00 ± 0.00
Week-9	CNT	5.33 ± 0.88	15.00 ± 1.53**	3.00 ± 1.00	2.67 ± 1.67	8.00 ± 1.53	12.00 ± 1.00	0.33 ± 0.33
	Se-treated	11.33 ± 2.03	9.00 ± 1.53	5.67 ± 1.67	4.67 ± 0.88	10.00 ± 1.15	21.33 ± 1.86*	0.67 ± 0.33
Week-10	CNT	8.33 ± 1.45	17.00 ± 1.53*	3.00 ± 1.00	2.67 ± 1.67	8.00 ± 1.53	12.00 ± 1.00	0.33 ± 0.33
	Se-treated	10.00 ± 1.15	11.00 ± 0.58	5.00 ± 1.53	5.67 ± 1.86	9.33 ± 1.33	11.00 ± 0.58	1.00 ± 0.58

The result was presented as mean ± SEM and analyzed using t-test, SPSS-version 16. CNT, control; se-treated, selenium-treated; (*), P ≤ 0.05; (**), P ≤ 0.01.

of ducks in selenium-treated group has been increased significantly, (P=0.002 each, $F_{(1,46)}$=18.151, $F_{(1,46)}$=33.021, in week-7, and week-8) compared with the control group. Meanwhile, the feed conversion ratio was highly decreased with organic selenium supplementation at ducks' finishing periods. Importantly, we noticed that the relative growth ratio was improved significantly with selenium supplementation in week-7 (0.37±0.04, p=0.006, $F_{(1,46)}$=16.443) compared to those ducks fed a basal diet (0.25±0.02). Also, it was increased at week-8 in a selenium supplemented group (0.21±0.04) compared to the controls (0.13±0.01), but with no significant differences.

Table 4: The performance of control and selenium supplemented diet groups of Muscovy duck from week-4 until week-10 of age.

Performance							
Items/ group	**Week-4**	**Week-5**	**Week-6**	**Week-7**	**Week-8**	**Week-9**	**Week-10**
Feed intake (g)/ CNT	616.67 ± 120.11	833.33 ± 132.22	1045.83 ± 222.22	1087.50 ± 225.11	1137.50 ± 180.11	1187.50 ± 193.22	1237.50 ± 212.33
Feed intake (g)/ se-treated	583.33 ± 111.22	862.50 ± 126.11	850.00 ± 100.44	1095.83 ± 143.23	1187.50 ± 144.55	1258.33 ± 198.33	1291.67 ± 155.34
Body weight (g)/ CNT	825.17 ± 21.38	1041.04 ± 29.66	1593.96 ± 43.61	2043.21 ± 52.12	2332.09 ± 65.39	2514.13 ± 76.48	2750.46 ± 85.84
Body weight (g)/ se-treated	864.54 ± 25.25	1088.63 ± 42.61	1588.59 ± 54.14	2317.79 ± 63.53**	2860.88 ± 67.90***	2988.13 ± 50.83***	3132.17 ± 73.03***
Weight gain (g)/ CNT	----	215.88 ± 39.45	552.92 ± 24.02	449.25 ± 32.71	288.88 ± 34.33	182.04 ± 68.48	236.33 ± 69.82
Weight gain (g)/ se-treated	----	224.08 ± 46.83	499.96 ± 51.22	729.21 ± 79.74**	543.08 ± 99.30**	127.25 ± 90.21	144.04 ± 79.93
Feed conversion (%)/ CNT	----	26 ± 1.9	53 ± 7.5	41 ± 6.4	25 ± 1.5	15 ± 0.5	19 ± 0.9
Feed conversion (%)/ se-treated	----	26 ± 2.3	59 ± 4.3	67 ± 9.4	46 ± 3.2	10 ± 1.2	11 ± 1.1
Relative growth (%)/ CNT	----	0.23 ± 0.04	0.42 ± 0. 01	0.25 ± 0.02	0.13 ± 0.01	0.07 ± 0.03	0.09 ± 0.03
Relative growth (%)/ se-treated	----	0.22 ± 0.04	0.37 ± 0.04	0.37± 0.04**	0.21 ± 0.04	0.05 ± 0.03	0.04 ± 0.03

The result presented as mean ± SEM and analyzed using t-test, SPSS version 16. CNT, control; se-treated, selenium-treated; (----), not detected; (*), P ≤ 0.05; (**), P ≤ 0.01; (***), P ≤ 0.001.

Table 5: Economic analysis (economic value and profitability ratio) of control and selenium-treated groups of Muscovy duck at week-10 of age.

Economic value	**Groups**		***P*-value**
	CNT	Se-treated	
Number of ducks/ treatments	**24**	**24**	
Weight (kg)/ duck	2.750 ± 0 .08	3.1338 ± 0.07***	0.001
Weight gain (kg)	1.926 ± 0.08	2.269 ± 0.08**	0.005
Feed intake (kg)/ duck	7.159 ± 0.25	7.128 ± 0.30	0.938
Feed conversion ratio	3.717 ±0.22*	3.141 ± 0.18	0.03
[1] Feed costs (AVC) $/ duck	2.534 ± 1.38	2.543 ±1.69	0.983
[2] Total costs (TC) $/ duck	4.469 ± 1.38	4.478 ± 1.66	0.682
[3] Total returns (TR) $/ duck	6.215 ± 3.00	7.082 ±2.55***	0.001
Net profit (NP) $/ duck	1.746 ± 3.40	2.603 ± 3.03**	0.006
Feed costs/ kg weight gain	1.315 ± 1.25*	1.121 ±1.04	0.038
Profitability ratio			
Benefit cost ratio (BCR)	1.39 ± 0.050	1.58 ± 0.057**	0.01
Profitability index (PI)	0.28 ± 0.021	0.37 ± 0.028**	0.008
Gross ratio (GR)	0.719 ± 0.030**	0.63 ± 0.029	0.009

Means are significantly different at P < 0.05. [1]Cost/kg diet= 0.354 $ and 0.357$ for CNT, control; and se, selenium-treated, respectively. [2]Total costs include fixed costs which consists of (price of duckling, labor, medicine) = 1.935$. [3]Price of one kg meat = 2.26 $. The result presented as mean ± SEM and analyzed using t-test, SPSS version 16. CNT, control; se-treated, selenium-treated; (*), P ≤ 0.05; (**), P ≤ 0.01; (***), P ≤ 0.001.

The significant role of selenium addition as anti-stress in Muscovey ducks ration

On the other hand, the TSH and T4 (see Figure 3) of Muscovy ducks in control group have been increased in week-7 (1.35 μg/dl, 0.07 μg/dl, p=0.043, $F_{(1,46)}$=11.006; p=0.132, $F_{(1,46)}$=7.361, respectively), in comparison with the selenium-treated group (0.98 μg/dl, 0.06 μg/dl).

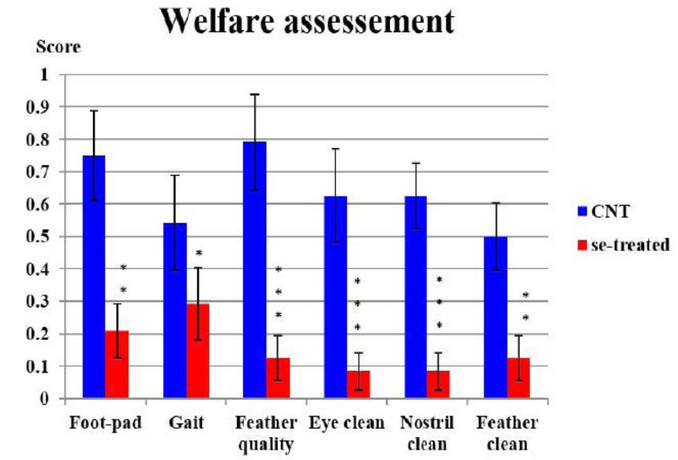

Figure 2: Welfare assessment scores in control and selenium supplemented diet groups of Muscovy duck, at week-10 of age. The result was presented as mean ± SEM and analyzed using *t*-test, SPSS-version 16. CNT, control; se-treated, selenium-treated; (*), $P \leq 0.05$; (**), $P \leq 0.01$; (***), $P \leq 0.01$.

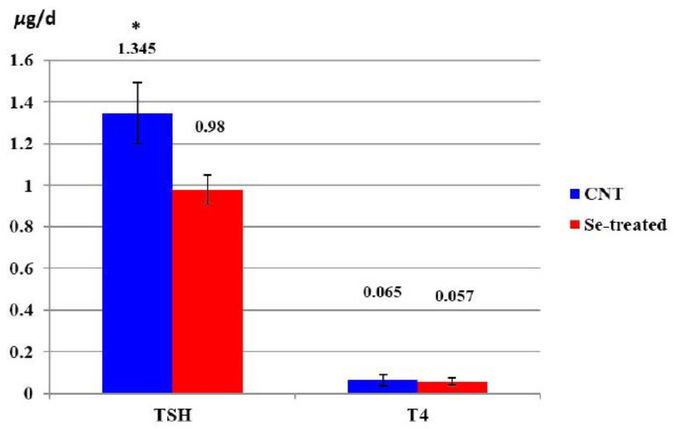

Figure 3: The level (*µ*g/dl) of thyroid stimulating hormone and thyroxine hormone in control and selenium supplemented diet groups of Muscovy duck at week-7 of age. The result was presented as mean ± SEM and analyzed using *t*-test, SPSS version 16; (*), $P \leq 0.05$.; CNT, control; se-treated, selenium-treated; TSH, thyroid-stimulating hormone; T4, thyroxine.

The economic analysis of adding selenium to Muscovey ducks ration

Economics analysis including economic values and profitability ratio were presented in Table 5. Results revealed non-significant differences (p=0.98, $F_{(1,46)}$=1.895) between the two treated groups regarding the feed cost and subsequently the total costs. The average total return (7.082±2.55 $/ duck) and net profit (2.603±3.03 $/ duck) for group fed selenium treated diet which were significantly (p=0.001, $F_{(1,46)}$=0.859) higher than the control group (6.215±3.00, 1.746±3.40) $/duck). The significantly (p=0.03, $F_{(1,46)}$=1.120) lowest cost/ kg gain presented in selenium treated group (1.156±1.04 $/ duck). Moreover, benefit costs ratio and profitability index were significantly higher (p=0.01, $F_{(1,46)}$=0.080; p=0.008, $F_{(1,46)}$=1.535) in selenium treated group (1.58±0.057), (0.37±0.02) than control group (1.39±0.057), (0.28±0.021) subsequently. Additionally, Gross ratio was the better in a selenium-treated group (0.63±0.029) compared with the control group (0.719±0.030).

Bird's behavior is the best indicator of managerial factor and welfare. To our background, this study is unique to emphasize the influences of organic selenium supplementation on behaviour, welfare, performance, thyroxine hormones level, and economic values in Muscovy ducks. We found that the feeding time was increased gradually with the age progress in selenium treatment. Similar results were obtained with Woods et al. (2020). Moreover, ingestive behavior is increased by dietary selenium alone or in combination with vitamin-E (Celi et al., 2010). As well, the drinking duration time (second) of ducks in control group has been increased compared to the selenium-treated group. Furthermore, the sitting duration time (second) of ducks in selenium-treated group has been increased significantly. It is well-known that the changes in the locomotor activities of birds are used as indicator of muscular dystrophy (Duncan, 2001) and related to improving number of lying and standing, and suppress number of walking ducks treated with selenium. In contrast the previous reported results (Nier et al., 2006). The aggression was increased with diet deficient in selenium (Sherwin and Kelland, 1998). In contrary, a reduced locomotor activity in control group in ducklings was recorded (Duncan, 2001). Concerning welfare soundness, this indicator can be improved with selenium supplementation and the worst signs of soundness; especially food pad dermatitis and feather quality occurred at caged duck without organic selenium supplementation. Herein, the organic selenium improved bird gait, eye, nose, and feather cleaning. These results were supported with (Mohammed et al., 2019). Direct contact of footpad with wire cage leaded to foot lesions, which characterized by inflammation and necrosis of foot, toe, and hock (Dawkins et al., 2017). Likewise, to our results, the prevalence of footpad dermatitis was significantly increased in the battery housing in ducks (Abdel-Hamid et al., 2020). Herein, the body weight and weight gain (gm) of ducks in selenium treated group increased significantly at the growing period. As well, as the feed conversion ratio was improved with dietary selenium supplementation at ducks' finishing periods also, the relative growth ratio was highly improved with dietary selenium supplementation. Consequently, the daily weight gain, feed intake and feed conversion ratio were not influenced by dietary selenium-treatments (Surai and Fisinin, 2014). On the other hand, selenium has a positive impact on the animal health, growth rate, and body weight of animals (Yoon et al., 2007).

Furthermore, the TSH and T4 (μg/dl) of ducks in control group have been increased significantly at week-7 compared to the selenium treatment one. The impact of selenium status on mood, behaviour, and cognition may be slightly regulated by changes influenced by selenium levels in thyroid function (Sher, 2000). As well, we reported that the capture of duck in cages increased hormonal stress-related leading to increase T4 (Abdel-Hamid et al., 2020). Regarding to the economic values, ducks are one of the most economic birds that is commonly raised with the purpose of consuming meat and eggs. This research showed that improvement in economic values (Total Return, Net Profit, Feed costs/ kg weight gain) and profitability ratio (Benefit cost ratio, Profitability index, Gross Ratio) was resulted from addition of selenium in duck diet. The weight gain, feed conversion ratio and subsequently profit and profitability ratio were improved without affecting on quantity and costs of feed intake. These results agreed with the previous report (Ali et al., 2019) who found that addition of selenium in duck ration up to 0.5 mg/kg feed enhanced body weight, feed conversion ratio and monetary indices. Similarity, using of selenium in broiler feed increased final weight and improved meat quality without increasing the cost of feed (Ibrahim et al., 2011). Therefore, from an economic point of view, it was clear in our results that using of 0.4 mg/kg achieved a better economic production according to the previous report (Zenunović and Glavić, 2018). Besides, the Muscovy duck would be ideal for small–scale rural farmers in Africa especially in Egypt and could contribute to food security. Therefore, a selenium-treated diet is essential to display the ducks' fundamental needs and/ or behaviour to maximize their welfare and productivities. However, further experiments should be done *in vivo* to evaluate the carcass traits and to emphasize the selenium level in blood and meat.

CONCLUSIONS AND RECOMMENDATIONS

The rearing of ducks inside their cages increased the possibility of discomfort and stressors, and therefore it considered a challenge refrains the bird's welfare. Herein, selenium clearly improved the feeding and sitting duration time of ducks than those of control group. Moreover, the body weight and weight gain of ducks in selenium-treated group have been clearly increased. Also, the feed conversion ratio was highly decreased with dietary selenium supplementation. Capture of duck in cages increased stress leading to increased thyroid hormones. Therefore, adding organic selenium to diet might be used as anti-stress and growth promoter in Muscovy ducks. Also, addition of 0.4 mg/kg organic-selenium showed a great economic values and profitability ratio in production of Muscovy duck.

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AUTHOR'S CONTRIBUTIONS

SEA, IFR and SES were mutually contributed by chemical, materials, and research methods in the manuscript, shared in the strategy and sample analysis. All authors took part in the analysis. They drafted, revised, and approved the manuscript.

CONFLICT OF INTERESTS

The authors have declared no conflict of interest.

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