

EFFECTS OF LIGHT REGIMENS AND VITAMIN D3 LEVELS AND THEIR INTERACTIONS ON BROILERS GROWTH PERFORMANCE AND CARCASS TRAITS.

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SUMMARY

The present study was designed to investigate the effect of light regimens and vitamin D3 levels on growth performance and some carcass traits of broiler chickens. Two hundred and seventy birds were randomly assigned in factorial design (3x3). Three light regimens (24 hrs continuous light, 12 hrs continuous with 12 hrs flashlight and 24 hrs flashlight) and three vitamin D3 levels (0, 200 and 400 IU). Nine treatments of 30 birds each (three replicates of 10 birds each). The birds were housed in floor pens from day one till six weeks of age. Feed and water were available ad lib. and all conditions were the same during the experimental period. The results showed that significantly affected body weight, daily weight gain and feed conversion ratio. In addition, birds reared under continuous with flashlight and feed with 200 IU Vit. D3 had significantly ($P \leq 0.05$) better body weight, daily weight gain, feed conversion and some carcass traits compared to the other groups. Finally, birds reared under continuous with flashlight and feed with 200 IU Vit. D3 was better than the other groups and was recommended to the poultry producer.

Keywords: *Broilers, light regimens, Vitamin D3 levels, Performance*

INTRODUCTION

Nelson et al., (2020) observed that birds in the intermittent, short-dawn/dusk photoperiod (ISD) treatment were heavier on day 45 of age. Olanrewaju et al., (2019) showed that broilers subjected to regular/intermittent photoperiod increased body weight on day 14, day 28, day 42, and day 56 of age. Farghly et al., (2019a) reported that the interaction between feeding regime and lighting program affected the growth performance. However, broilers exposed to flashing light and an intermittent feeding regime had the highest body weight (BW) values of all the groups. Olanrewaju et al., (2018) showed that broilers subjected to the short/non intermittent (8L:16D) photoperiod had the lowest body weight compared to other two photoperiods. Metwally et al., (2015) reported that light type significantly affected body weight.

Olanrewaju et al., (2019) showed that regular/intermittent photoperiod increased BWG on day 14, day 28, day 42, and day 56 of age in comparison with short/non-intermittent photoperiod. Arowolo et al., (2019) reported that various degrees of intermittent photo-period rather than one continuous photoperiod have been proven to significantly improve broilers' weight gain by 3.4-5.8%. Fidan et al., (2017) observed improvements in weight gain in a group of broilers subjected to increasing duration of photoperiod at 42 d compared to the birds on 23L: 1D treatment (2947.36 g vs. 2916.72 g) even though there was no significant difference in the feed consumed by the two groups. Subsequently, the distribution of photoperiod (light hours) and scot period (dark hours), which is one of the components of lighting program for broilers, has been reported to influence growth performance.

Olanrewaju et al., (2018) showed that broilers subjected to the short/non intermittent (8L:16D) photoperiod had the lowest feed consumption compared to other two photoperiods (long/continuous (23L:1D), regular/intermittent (2L:2D)), broilers reared under short/non-intermittent photoperiod had reduced feed intake on d 14, d 28, d 42, and d 56 of age compared with those subjected to long/continuous and regular/intermittent photoperiods.

In studies of Schwean-Lardner et al., (2016), Yang et al., (2015) and Aviagen (2014), improved feed conversion efficiency was observed in birds subjected to split darkness when compared to the continuous light group. Intermittent feeding and lighting have been used to improve feed efficiency (Farghly and Hassanien, 2012; Farghly and Makled, 2015). lighting programs with moderate photoperiod include the best results of feed conversion due to energy conservation during rest periods (dark) (Liboni et al., 2013). Abbas et al., (2008) reported significantly better FCR, in birds exposed to intermittent light of 2L:2D when compared to the near continuous light group. Kheiri and Landy (2019) reported that feed conversion ratio of broiler chickens fed basal diet supplemented with 1- α (OH)D₃ and 1500 or 3000 IU of cholecalciferol/kg of diet were significantly better than those fed basal diet, basal diet supplemented with 1- α (OH)D₃ alone or basal diet supplemented with 1- α (OH)D₃ and 5000 IU of cholecalciferol/ kg of diet. Cho et al., (2019) reported that at 14 D, 31 D and overall (0-31) FCR were not affected by dietary VD₃ levels. Okafor and Kalio (2017) reported that feed conversion ratio of broilers was not significantly different due to the effect of vitamin D₃ levels. Abbasi et al., (2017) reported that all experimental treatments did not influence feed conversion ratio and no significant differences were observed between treatments. Bozkurt et al., (2017) reported that feed conversion ratio was similar among dietary vitamin D₃ treatments. Landy et al., (2015) reported that the supplementation of 5000 IU cholecalciferol/kg of diet contained 5 μ g of 1- α (OH)D₃/kg of diet significantly decreased feed efficiency of broiler chickens during starter period. Khan et al., (2009) showed that feed efficiency (weight gain/feed intake) was significantly influenced by the treatments used at both 21 and 42 days of age. At both 21 and 42 days of age, the feed efficiency depressed significantly in broilers fed diet that had low level of VIT-D₃ (200 IU/kg) compared with other which fed high levels of VIT D₃ (1500, 2500 or 3500 IU/ kg) .

Olanrewaju et al., (2019) showed that broilers subjected to the short/non-intermittent photoperiod had the lowest carcass characteristics compared with values obtained for regular/ intermittent photoperiods. Farghly et al., (2019a) reported that the interaction between feeding regimes \times lighting programs broilers subjected to a restricted feeding regime \times flashing light had the lowest abdominal fat percentages of all the groups. Arowolo et al., (2019) reported that various degrees of intermittent photo-period (i.e. mixing photo and scoto - periods within 24 hours) rather than one continuous photoperiod have been proven to significantly improve broilers' carcass yield. Farghly et al., (2017) reported that light flashes program significantly improved carcass dressing percentage, breast percentage and abdominal fat percentage. Metwally et al., (2015) reported that light type significantly affected carcass traits. In studies of Schwean-Lardner et al., (2016). Olanrewaju et al., (2012) Indicated that long/continuous and regular/intermittent photoperiod equally improved broiler carcass characteristics compared with short/non-intermittent photoperiod. Farghly et al., (2019a) reported that lighting programs (100% continuous light or 50% continuous light and 50% flashing light) did not significantly change the carcass traits. Also, changes were not observed in spleen percentage of the broilers reared under the different lighting programs. Farghly et al., (2017) reported that light flashes program has insignificant effect in drumstick, femur, liver, heart and gizzard .

Okafor and Kalio (2017) reported that there was a significant difference in the weight of the gizzards at the 80% and 100% inclusion levels. Birds fed 100% inclusion levels of vitamin D₃ in their diet had the highest carcass weight. Dietary 25 OH D₃ supplementation has also been reported to improve breast meat yield as a result of increased muscle protein synthesis (Berri et al., 2013; Hutton et al., 2014; Vignale et al., 2015). Khan et al., (2010) showed that the dressing percentage and breast meat yield were better in birds fed diets containing 2500 or 3500 IU/Kg vitamin D₃. Paul et al., (2010) reported that increased vitamin supplementation in broiler diets significantly improved carcass composition of broilers. Pesti and Shivaprasad (2010) reported that no gross lesions or abnormalities were observed in the heart, kidney, bursa of Fabricius, pancreas, eye, intestine, liver, spleen, lungs, or skin tissue of control birds or broilers fed 1 α -OH-D₃ at any level (0, 5, 15, and 25 μ g/kg).

Therefore, the objective of this present study was to investigate the influence of lighting regimens and vitamin D₃ levels on the growth performance and carcass measurements of broilers.

MATERIALS AND METHODS

The current study was carried out at the Research Poultry Farm, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Management and experimental design

270 broiler chicks, One-day old from a common commercial strain (Sasso). chicks were divided into 9 treatments 30 birds each in three replicates 10 birds each in a factorial design (3x3). Three light regimens were used, 24hr continues light (C), 12hr continues light plus 12hr flash light (CF) and 24hr flash light (F). Three levels of vitamin D3 were used (Control level one, 200 ICU level two and level three 400 ICU/Kg). Based on the conversion of 0.025 µg to 1 ICU **NRC, 1994**. Chicks were wing-banded, weighed and housed in 27 rectangular pens (2 m²) the stocking density was 10 birds/m² on wheat straw litter floor with 6 Cm deep situated in thermostatically controlled building to provide the required temperature. The chicks were reared under 32 °C temperature as standard brooding temperature and 55% relative humidity during the first week, then gradually reduced 2 °C every three days to reach 24 °C and 55% relative humidity. The pens were lightproof by using double-layer black curtains on the windows. The light and dark cycles were obtained by using test light source controlled by automatic timer and dimmer to justify lighting periods and light intensity between 5 and 10 lux for each lighting group. Light source was incandescent bulb. Light flashes defined as a twenty light flashes per minute and they were generated by a flasher device that contained a timer and dimmer to justify lighting periods and intensity. Each pen was equipped with a feeder and a drinker. Chicks were provided with as much food and water as they wanted, and feed consumption was calculated at the end of each week. Chicks were provided with commercial feed according to age specifications. All diets were formulated to meet or exceed **NRC (1994)** recommendations for essential amino acids in starter diet containing (23% protein, ME 3000 Kcal. /Kg) from day one to twenty-one days old of age and grower diet containing (21% protein, ME 3100 Kcal. /Kg) from twenty-two days to forty-two days old of age (**NRC 1994**). The design as follow:

Group one (G1): Chicks were exposed to 24hr of continues light and fed a diet with level one (zero international chick unit of vitamin D3) of vitamin D3.

Group two (G2): Chicks were exposed to 24hr of continues light and fed a diet with level two (200 international chick unit of vitamin D3) of vitamin D3.

Group three (G3): Chicks were exposed to 24hr hours of continues light and fed a diet with level three (400 international chick unit of vitamin D3) of vitamin D3.

Group four (G4): Chicks were exposed to 12hr continues light plus 12hr flash light and fed a diet with level one (zero international chick unit of vitamin D3) of vitamin D3.

Group five (G5): Chicks were exposed to 12hr continues light with 12hr flash light and fed a diet with level two (200 international chick unit of vitamin D3) of vitamin D3.

Group six (G6): Chicks were exposed to 12hr continues light with 12hr flash light and fed a diet with level three (400 international chick unit of vitamin D3) of vitamin D3.

Group seven (G7): Chicks were exposed to 24hr of flash light and fed a diet with level one (zero international chick unit of vitamin D3) of vitamin D3.

Group eight (G8): Chicks were exposed to 24hr of flash light and fed a diet with level two (200 international chick unit of vitamin D3) of vitamin D3.

Group nine (G9): Chicks were exposed to 24hr of flash light and fed a diet with level three (400 international chick unit of vitamin D3) of vitamin D3.

Measured criteria

Body weights were recorded at one-day old, one, two, three, four, five and six weeks of age. chicks were individually weighed (± 1 gram). Body weight gains (BWG) and feed conversion ratio (FCR) were calculated at (0-1), (1-2), (2-3), (3-4), (4-5) and (5-6) weeks of age. Feed consumption was determined and calculated as gram feed/bird/day for the same time periods. At the end of the experiment (6 weeks of age), 27 birds were randomly taken as representative samples 3 birds per group; one bird per replicate, the birds were individually weighed, slaughtered by cutting the neck near the first cervical vertebra and then bled freely for 10 minutes, eviscerated to evaluate and to record carcass and measurements of the dressed carcass (carcass weight + giblets weight), edible viscera weight (Giblet = liver, heart and gizzard), breast meat yield, thigh, abdominal fat as percentages of the preslaughter weight were also recorded.

Statistical analysis

Data obtained from this study were tested for the significance of lighting treatments effect by ANOVA and GLM using the SAS procedure (version 9.2, 2009). Duncan's multiple range test (1955) was used to determine differences among means when treatment effects were significant. All data percentages of this study were transformed to Arcsine values before analysis. Significant differences were considered to exist when ($P < 0.05$).

The mathematical model was as follows:

$$Y_{ijk} = \mu + Li + Dj + (LD)_{ij} + E_{ijk}$$

Where: Y_{ijk} = any observation. μ = The population mean. Li = Lighting programs effect ($i = 1, 2$ and 3). Dj = Vitamin D3 levels effect ($j = 1, 2$ and 3). $(LD)_{ij}$ = Interaction of lighting programs \times vitamin D3 levels. E_{ijk} = Experimental error.

RESULTS AND DISCUSSIONS

1. Body weight

The results of body weight as affected by light regimens and vitamin D3 levels and their interactions presented in (Table 1). There were significant differences due to lighting programs at 3, 4, 5 and 6 weeks of age at ($P < 0.05$). Body weight of Sasso broiler chicks which exposed to a continues+flash lighting program were the same significantly affect as the effect of flash lighting program they both were higher than continues lighting programs. Regarding to the effect of vitamin D3 levels, there were significant differences on body weight at 3,4,5 and 6 weeks of age at ($P \leq 0.05$). There were insignificant effects at one-day old, one week and two weeks old of age. Chicks which fed on diet with vitamin D3 level 200IU/Kg were the same significantly affect as the effect of 400IU/Kg of Vit.D3 level so level 2 of Vit. D3 and level 3 is better than level one. There was significant affect due to the interaction between light program and vitamin D3 levels on body weight at all ages except the weights at one-day old, one week and two weeks old of age. Our results in agreement with Farghly et al., (2019a) reported that broilers exposed to flashing light had the highest body weight. Using flashing light may have aided early growth by providing more opportunity for the birds to reduce heat production and stimulate the secretory patterns of several hormones (Farghly and Makled, 2015; Farghly et al., 2016). Nelson et al., (2020) postulated that providing intermittent light with a short dawn/dusk period yielded heavier birds than did increasing day length with a long dawn/dusk period, probably because of differences in feeding behavior and physical activity. The obtained results are in agreement with others (Lien et al., 2007; Onbasilar et al., 2007). Lighting affects thyroid hormones and melatonin, which play major roles in growth and development (Zeman et al., 2004; Schwean-Lardner et al., 2016). Lien et al., (2007) proposed that the interaction of photoperiod is more influential on body weight than photoperiod alone .

In the contrast Bayram and Özkan (2010) reported that birds in the 16 L:8 D photoperiod treatment weighed less than those in the 24L treatment at 3 wk of age ($P \leq 0.05$) but were similar again by 6 wk of age. Body weights of broilers in the 16L:8D group reached those of broilers in the 24L group at slaughter age. Therefore, final BW were not affected by lighting treatment under the experimental conditions. Also, Lien et al., (2007) reported that there were interaction effects on BW at 29, 43, and 49 d. At 29 d, both 18L and 0.1FC (Foot Candle) treatments reduced BW. This effect was not only due to the increase in photoperiod from 18L:6D to 23L:1D during the last 6 d in the 18L treatment, because it was already underway at 43 d and occurred in the 0.1FC-18L but not the 1FC-18L treatment.

Reversely with Han et al., (2009) who reported that supplementation of 5 μ g 1- α (OH)D3/kg to broiler chicken diet containing 5 μ g cholecalciferol/kg had negative effects on BW of broiler chickens, which

Table (1): Effects of lighting programs, vitamin D3 levels and their interactions on body weights (g) of broiler chicks.

Age (Weeks) Treatments	Age (weeks)						
	1 day old	1	2	3	4	5	6
Lighting programs:							
Continues (C)	39.03±0.19	100.88±0.58	363.21±2.98	623.39±5.18 ^b	868.02±11.02 ^b	1048.41±9.81 ^b	1231.61±10.52 ^b
Continues+Flash (CF)	39.37±0.24	99.24±0.79	359.31±3.15	673.69±6.24 ^a	937.17±9.37 ^a	1124.72±8.39 ^a	1329.00±7.22 ^a
Flash (F)	39.15±0.28	99.74±0.60	358.04±2.31	663.36±6.48 ^a	918.06±8.33 ^a	1111.14±7.76 ^a	1316.98±8.93 ^a
<i>P</i> - value	0.6095	0.2010	0.4070	<.0001	<.0001	<.0001	<.0001
Vit. D3 levels:							
Control level 1 (L1)	39.32±0.22	99.34±0.59	361.16±3.37	623.83±5.74 ^b	854.03±9.78 ^b	1064.08±11.21 ^b	1261.75±11.35 ^b
200 IU level 2 (L2)	39.37±0.24	100.08±0.83	358.02±2.62	668.39±6.36 ^a	943.46±8.90 ^a	1102.02±7.30 ^a	1303.57±10.07 ^a
400 IU level 3 (L3)	38.87±0.26	100.44±0.54	361.38±2.46	668.22±5.95 ^a	925.17±9.13 ^a	1117.89±8.38 ^a	1311.13±8.19 ^a
<i>P</i> - value	0.2681	0.4917	0.6468	<.0001	<.0001	0.0001	0.0012
Interactions:							
(G1) C*L1	39.00±0.38	100.52±0.87	368.83±6.37	593.00±8.78 ^c	785.47±15.91 ^c	1010.89±23.77 ^d	1188.54±20.10 ^d
(G2) C*L2	39.03±0.32	100.97±1.13	356.40±5.66	633.83±8.19 ^b	914.17±18.63 ^{bcd}	1071.50±14.13 ^c	1241.62±21.53 ^c
(G3) C*L3	39.07±0.32	101.17±1.01	364.40±2.47	643.33±7.29 ^b	901.67±13.09 ^{cd}	1060.33±9.36 ^c	1255.76±9.52 ^c
(G4) CF*L1	39.30±0.40	98.30±1.22	359.93±5.17	648.75±8.90 ^b	880.50±12.28 ^d	1089.33±16.80 ^{bc}	1304.00±14.39 ^{ab}
(G5) CF*L2	39.83±0.46	99.73±1.96	363.33±4.61	693.33±10.48 ^a	978.67±12.78 ^a	1117.33±9.95 ^b	1333.83±10.77 ^a
(G6) CF*L3	38.97±0.39	99.70±0.55	354.67±6.50	679.00±11.58 ^a	952.33±17.79 ^{ab}	1167.50±12.61 ^a	1345.00±11.90 ^a
(G7) F*L1	39.65±0.40	99.22±0.92	354.72±5.78	629.75±9.58 ^b	895.21±15.23 ^{cd}	1089.31±13.65 ^{bc}	1284.16±17.19 ^{bc}
(G8) F*L2	39.23±0.44	99.53±1.09	354.33±2.87	678.00±11.40 ^a	937.34±11.75 ^{abc}	1117.76±11.90 ^b	1334.21±12.79 ^a
(G9) F*L3	38.57±0.59	100.47±1.13	365.07±2.25	682.33±10.32 ^a	921.50±15.34 ^{bcd}	1125.83±14.12 ^b	1331.45±14.95 ^a
<i>P</i> - value	0.5750	0.7588	0.2835	<.0001	<.0001	<.0001	<.0001

^{a-e} Means in the same columns in each classification with different superscript are significantly different ($P \leq 0.05$).

indicated that 1- α (OH)D₃, could not enhance growth performance indices of broiler chickens when basal diet contained adequate content of cholecalciferol.

2. Body weight gain

The results of body weight gain as affected by light regimens and vitamin D₃ levels and their interactions presented in (Table 2). There were significant differences due to lighting programs at three, six and the mean gain weeks of age at ($P \leq 0.05$). There were no significant differences at 1, 2, 4, and 5 weeks of age as affected by lighting programs. However, body weight gains of Sasso broiler chicks which exposed to the continues + flash lighting program were better than the other both continues and flash lighting programs. There were significant effects due to vitamin D₃ levels at 3, 4, 5, and the mean gain of weeks of age at ($P \leq 0.05$). There were no significant differences at the first, second and sixth weeks of age as affected by vitamin D₃ levels. However, broilers that had fed on diet with level two of vitamin D₃ was significantly equaled with level three of vitamin D₃ in the mean gain weeks of age, and they both were higher than the chicks which fed on level one of vitamin D₃. There were significant effects due to the interaction between lighting programs and vitamin D₃ levels on body weight gain at all ages except the first and second weeks of age. These results are in equal with Farghly et al., (2019a) reported that broilers exposed to flashing light regime had the highest BWG .

Reversely, Bayram and Özkan (2010) who reported that the mean daily BW gain of broilers from 3 to 6 wk was 89.7 g/d in the 16L:8D group and 86.6 g/d in the 24 L group. In this study, a constant photoperiod (16 L:8 D) beginning at 2 d of age reduced early growth, leading to a decrease in BW at 3 wk and in BW gain between 0 and 3 wk compared with broilers reared under the 24L photoperiod .

Same results with Cho et al., (2019) reported that at 14 D, the effect of dietary V D₃ levels on body weight gain was mathematically significant between the groups that received V D₃ 200 IU/kg of feed and 3,125 IU/kg of feed, and the highest weight gain was observed in birds fed with V D₃ at 3,125 IU/kg of feed. Increasing VD₃ from 300 IU/kg to 1,200 IU/kg improved BW gain in broilers at 17 D and 35 D (Ramo Rao et al., 2009). Also. Khan et al., (2009) showed that maximum body weight was gained by supplementing 1500 to 3500 IU/kg of VIT-D₃. The major circulating form of vitamin D₃, 25-hydroxycholecalciferol (25 OH D₃), has been shown to improve body weight (BW) gain (Garcia et al., 2013) .

3. Feed consumption

The results of feed consumption as affected by light regimens and vitamin D₃ levels and their interactions presented in (Table 3). There were no significant differences due to lighting programs on feed consumption at all ages. However, feed consumption of Sasso broiler chicks which exposed to the flash lighting program were lower consumption than the other both lighting programs numerically. Regarding with the effect of vitamin D₃ levels, there were no significant differences on feed consumption at all ages. There were insignificant effects due to the interactions between light programs and vitamin D₃ levels on feed consumption at all ages. Same results like Farghly et al., (2019b) who reported that no significant effect on feed consumption due to lighting programs. Also, Bayram and Özkan (2010) who reported that total feed consumption was 3.44 and 3.31 kg/bird for birds in the 16L:8D and control group, respectively, and there was no difference between groups .

Reversely, Amakiri et al., (2011) revealed that birds on restricted light regimens can maintain a FC similar to those under continuous illumination by increasing their rate of consumption per unit of illumination time. Sun et al., (2017) reported that during the finishing stage (d 56–91), the average daily feed intake (ADFI) of broiler chickens under 16L:8D regimen was greater than those of other regimens.

Same result with, Adhikari et al., (2020) showed that there was no difference in FI between hens fed diets supplemented with different levels of vitamin D₃ and 25-OHD. Kheiri and Landy (2019) who stated that in starter period, there were no significant differences between vitamin D₃ dietary treatments for daily feed intake (DFI).

Reversely, Adhikari et al., (2020) showed that hens fed the diet supplemented with 3,000 IU of vitamin D₂ had significantly higher ($P < 0.05$) FI compared to hens fed the diet supplemented with 9,000 IU. And, Han et al., (2009) who reported that supplementation of 5 μ g 1- α (OH)D₃/kg to broiler chicken diet containing 5 μ g cholecalciferol/kg had negative effects on DFI of broiler chickens.

4. Feed conversion ratio

The results of feed conversion ratio as affected by light regimens and vitamin D₃ levels and their interactions presented in (Table 4). There were significant differences due to lighting programs at the intervals between (2-3), the mean FCR and total weeks of age at ($P \leq 0.05$). However, feed conversion ratio of Sasso broiler chicks which exposed to a flash lighting and continues+flash lighting programs were the best lighting program. The rest of the other ages had no significant effects. Chicks which fed on diet with level 2 and 3 of vitamin D₃ were the same significantly effect. Level 2 and 3 of Vit. D₃ was better than the level 1. While, the rest of the other ages had no significant effects. The groups were raised under the continues + flash lighting program, flash program and fed on diet with level two and three of vitamin D₃ were better than the other treatments. Our study in agreement with Farghly et al., (2019a) who reported that broilers

Table (2): Effects of lighting programs, vitamin D3 levels and their interactions on body weight gain (g) of broiler chicks.

Age (Weeks) Treatments	Age (weeks)							Mean	1-6
	1	2	3	4	5	6			
Lighting programs:									
Continues (C)	8.84±0.07	37.48±0.41	37.17±0.65 ^b	34.79±1.14	26.78±1.26	25.75±0.93 ^b	28.58±0.31 ^b	1144.06±17.38 ^b	
Continues+Flash (CF)	8.55±0.10	37.15±0.44	44.91±0.88 ^a	37.64±1.02	26.79±1.19	28.42±0.98 ^a	30.58±0.20 ^a	1273.22±10.47 ^a	
Flash (F)	8.66±0.09	36.90±0.35	43.62±0.93 ^a	36.50±0.92	27.58±1.15	29.14±0.86 ^a	30.40±0.21 ^a	1257.72±13.56 ^a	
P- value	0.0758	0.5940	<.0001	0.1438	0.8618	0.0290	<.0001	<.0001	
Vit. D3 levels:									
Control level 1 (L1)	8.58±0.08	37.40±0.49	37.52±0.84 ^b	32.90±0.85 ^b	30.09±0.93 ^a	26.71±0.78	28.83±0.30 ^b	1168.89±18.56 ^b	
200 IU level 2 (L2)	8.67±0.10	36.85±0.34	44.34±0.80 ^a	39.29±1.02 ^a	23.40±1.30 ^b	29.46±1.11	30.48±0.24 ^a	1239.92±14.94 ^a	
400 IU level 3 (L3)	8.80±0.08	37.28±0.35	43.83±0.88 ^a	36.71±1.11 ^a	27.53±1.22 ^b	27.34±0.84	30.25±0.19 ^a	1266.18±9.09 ^a	
P- value	0.2114	0.5908	<.0001	<.0001	0.0003	0.0956	<.0001	<.0001	
Interactions:									
(G1) C*L1	8.79±0.11	38.33±0.89	32.02±1.04 ^c	27.15±1.24 ^d	32.92±1.55 ^a	23.02±1.33 ^c	26.93±0.55 ^d	1068.67±37.61 ^d	
(G2) C*L2	8.85±0.14	36.49±0.75	39.63±0.77 ^b	40.05±2.12 ^a	25.01±2.64 ^{bcd}	25.71±2.06 ^{bc}	29.84±0.61 ^{bc}	1153.17±29.81 ^c	
(G3) C*L3	8.87±0.13	37.60±0.32	39.85±0.89 ^b	36.90±1.61 ^{abc}	22.67±1.89 ^{cd}	27.94±1.31 ^{ab}	28.98±0.22 ^c	1210.33±11.28 ^{bc}	
(G4) CF*L1	8.43±0.17	37.38±0.75	41.26±1.03 ^b	33.11±1.16 ^c	29.83±1.44 ^{ab}	29.07±1.49 ^{ab}	29.83±0.43 ^{bc}	1219.62±24.48 ^{bc}	
(G5) CF*L2	8.56±0.22	37.66±0.56	47.14±1.39 ^a	40.76±1.70 ^a	19.81±1.77 ^d	30.93±1.84 ^a	30.81±0.26 ^{ab}	1294.00±10.82 ^a	
(G6) CF*L3	8.68±0.09	36.42±0.93	46.33±1.86 ^a	39.05±2.08 ^{ab}	30.74±2.28 ^{ab}	25.36±1.54 ^{bc}	31.10±0.28 ^a	1306.03±11.87 ^a	
(G7) F*L1	8.51±0.13	36.50±0.88	39.29±1.66 ^b	38.44±1.24 ^{ab}	27.73±1.73 ^{abc}	27.64±1.01 ^{abc}	29.72±0.39 ^{bc}	1218.40±25.23 ^{bc}	
(G8) F*L2	8.61±0.14	36.40±0.41	46.24±1.47 ^a	36.98±1.35 ^{abc}	25.77±2.32 ^{bc}	30.92±1.81 ^a	30.80±0.30 ^{ab}	1272.60±25.52 ^{ab}	
(G9) F*L3	8.84±0.20	37.80±0.36	45.32±1.44 ^a	34.17±1.98 ^{bc}	29.19±1.91 ^{ab}	28.80±1.48 ^{ab}	30.68±0.36 ^{ab}	1282.17±17.95 ^{ab}	
P- value	0.3400	0.3463	<.0001	<.0001	<.0001	0.0076	<.0001	<.0001	

^{a-d} Means in the same columns in each classification with different superscript are significantly different ($P \leq 0.05$).

Table (3): Effects of lighting programs, vitamin D3 levels and their interactions on feed consumption (g/b/d) of broiler chicks.

Age (Weeks) Treatments	Age (weeks)						Mean	1 - 6
	0 – 1	1 – 2	2 – 3	3 – 4	4 – 5	5 – 6		
Lighting programs:								
Continues (C)	18.22±0.40	46.67±0.83	51.31±1.87	56.81±1.60	58.81±1.60	77.66±0.75	51.58±0.66	2166.34±27.53
Continues+Flash (CF)	18.27±0.43	46.44±0.82	51.29±1.57	51.89±2.16	56.89±2.16	77.07±0.51	50.31±1.03	2112.91±43.19
Flash (F)	18.32±0.39	46.21±0.67	50.74±0.92	51.57±1.41	53.57±1.41	76.50±0.67	49.49±0.48	2078.38±20.26
<i>P</i> - value	0.9849	0.9178	0.9556	0.0801	0.1231	0.4644	0.1652	0.1652
Vit. D3 levels:								
Control level 1 (L1)	18.33±0.48	47.24±1.07	52.97±1.53	55.03±1.46	58.03±1.58	77.79±0.68	51.57±0.77	2165.80±32.26
200 IU level 2 (L2)	18.28±0.27	46.19±0.47	50.23±1.44	53.70±2.42	56.70±2.25	77.13±0.48	50.37±0.91	2115.63±38.04
400 IU level 3 (L3)	18.20±0.44	45.89±0.58	50.14±1.32	51.53±1.61	54.53±1.62	76.30±0.72	49.43±0.55	2076.20±23.06
<i>P</i> - value	0.9732	0.4207	0.3044	0.4267	0.4132	0.2703	0.1569	0.1569
Interactions:								
(G1) C*L1	17.50±0.29	47.83±2.17	53.13±3.22	55.50±1.44	57.50±1.44	78.70±1.30	51.69±0.49	2171.17±20.41
(G2) C*L2	18.33±0.60	46.00±1.04	51.97±4.23	61.43±2.25	63.43±2.25	77.77±0.73	53.16±0.97	2232.53±40.53
(G3) C*L3	18.83±1.01	46.17±1.20	48.83±2.95	53.50±2.60	55.50±2.60	76.50±1.81	49.89±1.15	2095.33±48.09
(G4) CF*L1	19.00±1.15	47.33±2.33	52.77±4.15	55.50±4.33	60.50±4.33	77.67±0.88	52.13±2.41	2189.37±101.25
(G5) CF*L2	17.97±0.26	46.33±0.67	49.50±1.65	49.50±4.27	54.50±4.27	76.20±0.99	49.00±1.72	2058.00±72.17
(G6) CF*L3	17.83±0.60	45.67±1.20	51.60±2.61	50.67±2.96	55.67±2.96	77.33±0.88	49.79±1.13	2091.37±47.51
(G7) F*L1	18.50±0.87	46.57±1.79	53.00±0.75	54.10±2.06	56.10±2.06	77.00±1.53	50.88±0.79	2136.87±33.37
(G8) F*L2	18.53±0.58	46.23±1.03	49.23±1.45	50.17±1.42	52.17±1.42	77.43±0.72	48.96±0.39	2056.37±16.35
(G9) F*L3	17.93±0.81	45.83±1.01	50.00±1.86	50.43±3.58	52.43±3.58	75.07±0.93	48.62±0.73	2041.90±30.45
<i>P</i> - value	0.8784	0.9802	0.9147	0.1784	0.2196	0.5800	0.1794	0.1794

All values were not significant in each classification (P≤0.05).

Table (4): Effects of lighting programs, vitamin D3 levels and their interactions on feed conversion ratio (gain feed/ gain weight) of broiler chicks.

Age (Weeks) Treatments	Age (weeks)						Mean	1 – 6
	0 – 1	1 – 2	2 – 3	3 – 4	4 – 5	5 – 6		
Lighting programs:								
Continues (C)	2.06±0.04	1.25±0.02	1.40±0.09 ^a	1.68±0.10	2.32±0.21	3.14±0.19	1.81±0.03 ^a	1.90±0.05 ^a
Continues+Flash (CF)	2.14±0.05	1.25±0.02	1.15±0.05 ^b	1.42±0.11	2.24±0.18	2.76±0.13	1.65±0.04 ^b	1.66±0.05 ^b
Flash (F)	2.12±0.05	1.25±0.03	1.17±0.05 ^b	1.42±0.06	1.96±0.08	2.67±0.10	1.63±0.03 ^b	1.65±0.03 ^b
<i>P</i> - value	0.5540	0.9706	0.0199	0.0902	0.2805	0.0708	0.0014	0.0006
Vit. D3 levels:								
Control level 1 (L1)	2.14±0.06	1.26±0.03	1.43±0.08 ^a	1.72±0.12 ^a	1.94±0.05 ^b	2.98±0.14	1.79±0.04 ^a	1.86±0.05 ^a
200 IU level 2 (L2)	2.11±0.04	1.25±0.02	1.14±0.05 ^b	1.38±0.06 ^b	2.49±0.17 ^a	2.78±0.22	1.65±0.04 ^b	1.72±0.07 ^{ab}
400 IU level 3 (L3)	2.07±0.05	1.23±0.02	1.15±0.04 ^b	1.43±0.07 ^b	2.09±0.19 ^{ab}	2.81±0.08	1.64±0.03 ^b	1.64±0.03 ^b
<i>P</i> - value	0.6302	0.6043	0.0029	0.0206	0.0429	0.6342	0.0092	0.0167
Interactions:								
(G1) C*L1	1.99±0.06	1.25±0.05	1.66±0.13 ^a	2.04±0.04 ^a	1.76±0.10 ^b	3.43±0.11	1.92±0.04 ^a	2.03±0.03 ^a
(G2) C*L2	2.07±0.06	1.26±0.04	1.31±0.12 ^{bc}	1.55±0.08 ^{bc}	2.68±0.37 ^a	3.26±0.54	1.78±0.03 ^b	1.94±0.09 ^{ab}
(G3) C*L3	2.12±0.11	1.23±0.04	1.23±0.11 ^{bc}	1.46±0.11 ^{bc}	2.52±0.35 ^{ab}	2.74±0.06	1.72±0.03 ^{bc}	1.73±0.03 ^{cd}
(G4) CF*L1	2.25±0.11	1.27±0.05	1.28±0.11 ^{bc}	1.71±0.24 ^{ab}	2.03±0.02 ^{ab}	2.73±0.29	1.75±0.08 ^b	1.80±0.09 ^{bc}
(G5) CF*L2	2.10±0.08	1.23±0.02	1.05±0.02 ^c	1.22±0.12 ^c	2.75±0.17 ^a	2.50±0.20	1.59±0.04 ^c	1.59±0.04 ^d
(G6) CF*L3	2.05±0.06	1.26±0.03	1.12±0.03 ^{bc}	1.33±0.12 ^{bc}	1.95±0.40 ^{ab}	3.06±0.08	1.60±0.04 ^c	1.60±0.04 ^d
(G7) F*L1	2.17±0.07	1.28±0.08	1.35±0.04 ^b	1.41±0.12 ^{bc}	2.02±0.04 ^{ab}	2.79±0.06	1.71±0.04 ^{bc}	1.75±0.01 ^{cd}
(G8) F*L2	2.15±0.10	1.27±0.02	1.07±0.01 ^c	1.36±0.03 ^{bc}	2.05±0.24 ^{ab}	2.59±0.30	1.59±0.03 ^c	1.62±0.05 ^d
(G9) F*L3	2.03±0.12	1.21±0.04	1.11±0.04 ^{bc}	1.49±0.13 ^{bc}	1.80±0.07 ^b	2.63±0.13	1.58±0.01 ^c	1.59±0.01 ^d
<i>P</i> - value	0.5973	0.9762	0.0013	0.0091	0.0521	0.1721	0.0003	<.0001

^{a-d} Means in the same columns in each classification with different superscript are significantly different ($P \leq 0.05$).

exposed to flashing light regime had the lowest FCR. And, Farghly et al., (2019b) reported that hens exposed to intermittent lights for 20 min/h + 40 min of constant light had the lowest FCR when compared with the other groups .

On the other hand, Bayram and Özkan (2010) who reported that FCR were not affected by lighting treatment under the experimental conditions. Amakiri et al., (2011) reported insignificant differences in the FCR of broilers subjected to varying nocturnal lighting programs. Sun et al., (2017) reported that the FCR of broilers under the 3L:1D regimen was high.

We in an agreement with, Kheiri and Landy (2019) who reported that FCR it tended to improve in broiler chickens supplemented with 1- α (OH) D₃ in combination with different concentrations of cholecalciferol in compare with broiler chickens fed basal diet or basal diet supplemented with 1- α (OH) D₃ alone .

Conversely, Landy et al., (2015) who reported that the supplementation of 5000 IU cholecalciferol/kg of diet contained 5 μ g of 1- α (OH) D₃/kg of diet significantly decreased feed efficiency of broiler chickens during starter period although it had not any significant effect on growth performance of broiler chickens during grower and finisher phases.

5. Carcass traits

The results of carcass traits as affected by light regimens and vitamin D₃ levels and their interactions presented in (Table 5). There were insignificant effects due to the lighting programs on carcass traits of Sasso chicks except, the effect on abdominal fat it was significant at ($P \leq 0.05$). The chicks which raised under flash lighting program were the lowest than other lighting groups. Chicks which fed on diet with level 2 and 3 of vitamin D₃ were the same significantly effect on thigh percentage they were higher than chicks which fed on diet with level 1 of vit. D₃. While, chicks which fed on diet with level 2 and 3 of vitamin D₃ were the same significantly effect on giblets percentage they were lower than chicks which fed on diet with level 1 of vit. D₃. the rest of carcass traits had insignificant effects. There was insignificant effect due to the interaction between lighting programs and vitamin D₃ levels on carcass traits except, the effect on abdominal fat it was significant at ($P \leq 0.05$) the chicks in groups 7, 8, and 9 which raised under flash lighting program were lowest than other groups.

Our study in same line with Farghly et al., (2019a) who reported that lighting programs did not significantly change the carcass traits. Also, Farghly and Makled (2015) they found non-significant differences in the percentages of the dressed carcass, drumstick, femur, breast, heart, and gizzard among all groups under light flashes, although the differences were significant ($P < 0.05$) in the drumstick, liver and abdominal fat percentages. And, this result was consistent with the findings of Downs et al., (2006), who reported no significant effect in the cold carcass yield of birds exposed to different lighting program .

Reversely Olanrewaju et al., (2019) who showed that regular/intermittent photoperiod had higher live weight ($P = 0.043$), carcass weight ($P = 0.037$), carcass yield ($P = 0.034$), and breast weight ($P = 0.035$) in comparison with short/non-intermittent photoperiod. Lien et al., (2007) reported that an interaction effect on chilled carcass weight resulted in the 0.1FC-23L treatment carcass weight being reduced an average of 78 g relative to the other 3 treatments. Intermittent lighting treatment effects reported by Das and Lacin (2014) caused lower breast yield in broilers when compared to CL (42.62% vs. 44.76%). However, Schwan-Lardner and Classen (2010) reported increased carcass yield with increasing length of photoperiod. Furthermore, these researchers observed an increase in breast meat yield and decreased whole leg percentage with increasing photoperiod length, in parallel to what was obtained from the studies of Downs et al., (2006) and Fidan et al. (2017) .

This result was consistent with the findings of Khan et al., (2009) showed that values of dressing percentage and breast meat yield in different groups indicated that there was no marked variation up to 1500 IU/kg VIT-D₃ supplementation. Statistical analysis showed insignificant ($p > 0.05$) results in above parameters of broiler between levels of VIT-D₃ 200 and 1500 IU/kg However, birds fed diet with higher levels of VIT-D₃ had significantly ($p < 0.05$) the highest dressing percentage and breast meat yield. Our study in same line with Farghly et al., (2019a) who reported that lighting programs didn't significantly change the carcass traits. This result was consistent with the findings of Khan et al., (2009) who showed that values of dressing percentage and breast meat yield in different groups indicated that there was no marked variation up to 1500 IU/kg VIT-D₃ supplementation.

6. Some body organs

The effects of lighting programs, vitamin D₃ levels and their interactions on some body organs of Sasso broiler chicks are presented in (Table 6).

There was significant difference due to lighting programs on gall bladder at ($P \leq 0.05$). There were insignificant effects due to the lighting programs on the rest of a body organs of Sasso chicks.

There was a significant effect due to vitamin D3 levels on heart and pancreas percentage at ($P \leq 0.05$). However, Chicks which fed on diet with level 2 and 3 of vitamin D3 were the same significantly effect on heart and pancreas percentages they were higher than chicks which fed on diet with level 1 of vit. D3. There was an interactions effect between lighting programs and vitamin D3 levels on liver, gizzard, pancreas and gall bladder percentages significantly at ($P \leq 0.05$).

These findings partially agree with those reported by Farghly and Makled (2015) who they found that flash lighting significantly affected on liver percentages. And, Abreu et al., (2011) who showed that lighting programs did not affect the heart, liver, gizzard, and abdominal fat percentages.

CONCLUSION

The results of this study indicated that supplement of vitamin D3 and continuous plus flash lighting program improved growth performance until marketing age.

Table (5): Effects of lighting programs, vitamin D3 levels and their interactions on carcass traits of broiler chicks.

Treatment	Carcass trait						
	Live BW (g)	Carcass %	Breast %	Thigh %	D. carcass %	Giblets %	Abdominal fat %
Lighting programs:							
Continues (C)	1219.44±15.58	66.23±0.62	21.95±0.59	13.54±0.61	71.10±0.74	4.87±0.22	2.19±0.03 ^a
Continues+Flash (CF)	1251.67±35.18	68.18±0.66	22.05±0.56	12.41±0.56	73.02±0.66	4.84±0.12	2.15±0.06 ^a
Flash (F)	1222.78±23.19	66.94±0.79	22.49±0.57	13.00±0.68	71.77±0.90	4.83±0.23	1.71±0.03 ^b
<i>P</i> - value	0.6326	0.1535	0.7812	0.4463	0.2238	0.9915	<.0001
Vit. D3 levels:							
Control level 1 (L1)	1255.56±29.14	67.74±0.44	21.52±0.60	11.67±0.35 ^b	73.06±0.43	5.32±0.17 ^a	1.96±0.09
200 IU level 2 (L2)	1211.67±27.35	67.58±0.60	22.64±0.62	13.68±0.61 ^a	72.08±0.64	4.50±0.06 ^b	2.05±0.09
400 IU level 3 (L3)	1226.67±19.36	66.04±0.95	22.34±0.43	13.60±0.64 ^a	70.76±1.05	4.72±0.20 ^b	2.03±0.08
<i>P</i> - value	0.4799	0.1869	0.3502	0.0251	0.1171	0.0028	0.7662
Interactions:							
(G1) C*L1	1218.33±31.80	67.88±0.73	20.91±1.25	12.03±0.41 ^{abc}	73.20±1.03	5.32±0.31	2.18±0.06 ^a
(G2) C*L2	1201.67±29.06	65.92±0.74	22.82±1.02	14.58±1.51 ^{ab}	70.19±0.66	4.28±0.09	2.23±0.07 ^a
(G3) C*L3	1238.33±26.82	64.90±1.11	22.13±0.80	14.01±0.49 ^{abc}	69.90±1.33	5.01±0.42	2.14±0.06 ^a
(G4) CF*L1	1295.00±70.00	67.65±0.85	21.76±1.06	11.45±0.99 ^c	72.83±0.69	5.18±0.23	2.07±0.10 ^a
(G5) CF*L2	1233.33±83.33	69.54±0.48	21.98±1.46	13.93±0.92 ^{abc}	74.19±0.46	4.65±0.03	2.17±0.14 ^a
(G6) CF*L3	1226.67±39.83	67.36±1.69	22.42±0.63	11.84±0.37 ^{bc}	72.04±1.84	4.68±0.16	2.21±0.06 ^a
(G7) F*L1	1253.33±52.94	67.69±1.05	21.88±1.15	11.52±0.46 ^c	73.14±0.82	5.45±0.41	1.63±0.07 ^b
(G8) F*L2	1200.00±28.87	67.27±0.43	23.13±1.04	12.53±0.54 ^{abc}	71.85±0.42	4.58±0.00	1.74±0.04 ^b
(G9) F*L3	1215.00±45.37	65.86±2.30	22.47±1.08	14.95±1.39 ^a	70.33±2.61	4.47±0.42	1.75±0.06 ^b
<i>P</i> - value	0.9293	0.2872	0.9277	0.0569	0.2621	0.0927	<.0001

^{a-c} Means in the same columns in each classification with different superscript are significantly different $P \leq 0.05$

Table (6): Effects of lighting programs, vitamin D3 levels and their interactions on some body organs of broiler chicks.

Treatment	Some body organs				
	Liver%	Gizzard%	Heart%	Pancreas%	Gall bladder%
Lighting programs:					
Continues (C)	2.56±0.12	1.93±0.18	0.37±0.02	0.18±0.02	0.10±0.01 ^a
Continues+Flash	2.37±0.15	2.11±0.07	0.36±0.02	0.16±0.02	0.08±0.01 ^b
Flash (F)	2.53±0.16	1.90±0.11	0.40±0.02	0.20±0.02	0.08±0.00 ^b
<i>P</i> - value	0.6115	0.4791	0.4352	0.2376	0.0077
Vit. D3 levels:					
Control level 1	2.94±0.10 ^a	2.05±0.08	0.33±0.02 ^b	0.13±0.01 ^b	0.08±0.00
200 IU level 2	2.16±0.08 ^b	1.95±0.13	0.39±0.02 ^a	0.19±0.01 ^a	0.09±0.00
400 IU level 3	2.35±0.10 ^b	1.95±0.17	0.42±0.02 ^a	0.21±0.01 ^a	0.08±0.01
<i>P</i> - value	0.0001	0.8377	0.0068	0.0004	0.1837
Interactions:					
(G1) C*L1	3.00±0.15 ^a	2.00±0.17 ^{abc}	0.31±0.02	0.12±0.02 ^c	0.10±0.01 ^a
(G2) C*L2	2.40±0.10 ^{bc}	1.46±0.04 ^c	0.42±0.05	0.19±0.01 ^{ab}	0.10±0.01 ^a
(G3) C*L3	2.29±0.05 ^c	2.33±0.40 ^a	0.39±0.02	0.23±0.01 ^a	0.10±0.01 ^a
(G4) CF*L1	2.87±0.21 ^{ab}	2.00±0.09 ^{abc}	0.31±0.06	0.14±0.01 ^{bc}	0.08±0.01 ^{ab}
(G5) CF*L2	1.94±0.10 ^c	2.34±0.10 ^a	0.37±0.03	0.14±0.01 ^{bc}	0.10±0.00 ^a
(G6) CF*L3	2.29±0.09 ^c	2.00±0.07 ^{abc}	0.40±0.01	0.19±0.04 ^{ab}	0.06±0.01 ^b
(G7) F*L1	2.95±0.24 ^a	2.14±0.20 ^a	0.36±0.04	0.14±0.02 ^{bc}	0.08±0.01 ^{ab}
(G8) F*L2	2.16±0.02 ^c	2.04±0.04 ^{ab}	0.38±0.02	0.24±0.01 ^a	0.09±0.01 ^{ab}
(G9) F*L3	2.47±0.32 ^{abc}	1.53±0.09 ^{bc}	0.47±0.01	0.22±0.01 ^a	0.07±0.00 ^b
<i>P</i> - value	0.0023	0.0218	0.0704	0.0013	0.0158

^{a-c} Means in the same columns in each classification with different superscript are significantly different $P \leq 0.05$.

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تأثير برامج الإضاءة و مستويات فيتامين د³ و التداخل بينهم على أداء نمو دجاج التسمين

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أجريت هذه الدراسة على مئتين و سبعون طائر من سلالة ساسو التسمين التجارية لتقييم تأثير برامج إضاءة مختلفة و مستويات مختلفة فيتامين د³ و التداخل بينهم على اداء الطيور و خصائص الذبيحة. قسمت الطيور عشوائيا الى تسع معاملات ثلاثون طائر لكل منها من عمر يوم وحتى ٤٢ يوم. تم اسكان الطيور تحت ثلاث برامج إضاءة مختلفة: (برنامج اربعة وعشرون ساعة إضاءة مستمرة - برنامج اثنا عشر ساعة إضاءة مستمرة واثنا عشر ساعة إضاءة وميض - برنامج اربعة وعشرون ساعة إضاءة وميض) و غذيت كل مجموعة على علائق مزودة بمستويات مختلفة من فيتامين د³، (المستوى الاول بدون إضافة من فيتامين د³، المستوى الثانى مضاف للعليقة مئتان وحدة دولية من فيتامين د³ ، المستوى الثالث مضاف للعليقة أربعمئة وحدة دولية من فيتامين د³).

أشارت النتائج الى وجود تأثير معنوي لكل من الإضاءة و فيتامين د³ و التداخل بينهم على وزن الجسم و الزيادة فى وزن الجسم و معامل التحويل الغذائى. لم تتأثر صفات الذبيحة سوى دهن الجسم بالإضاءة. فيتامين د³ اثر معنويا على وزن الفخذ و الحواضج و تأثرت الحوصلة المرارية معنويا بالإضاءة و ان فيتامين د³ اثر معنويا على النسبة المئوية لكلا من الكبد و البنكرياس و القلب، و خلصت النتائج الى ان برنامج الإضاءة (١٢ ساعة إضاءة مستمرة + ١٢ ساعة إضاءة بالوميض) مع فيتامين د³ بمستوى ٢٠٠ او ٤٠٠ وحدة دولية هو الذى اعطى افضل النتائج بالنسبة للصفات المدروسة.