



## Influences of dietary crude protein and stocking density on growth performance and body measurements of ostrich chicks

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**Abstract:** Thirty-six African Black ostrich chicks were used to investigate the effects of dietary crude protein (CP) levels (180, 210 and 240 g/kg), stocking density (4.5 and 3 m<sup>2</sup>/bird) and their interactions. A factorial arrangement was used to examine the impact of treatments on growth performance and body measurements of ostrich chicks during 2 to 10 weeks of the age. Results indicated that factors studied did not change growth performance traits. The highest value of protein efficiency ratio was observed in ostrich chicks fed diet contained 240 g/kg diet. Birds fed diet contained 240 g CP /kg diet and kept at stocking density of 3 m<sup>2</sup> per bird had numerically the highest protein efficiency ratio. Shank girth and tibiotarsus length decreased with increasing dietary CP level. Stocking density did not change values of body measurements, except tibiotarsus length at 6 weeks of age, which increased in birds kept at the lower density than the higher. Body height at 10 weeks of age was significantly affected by the interactions between dietary CP and stocking density. In conclusion, results affirmed that ostrich chicks can grow on diets containing low levels of CP (180-210 g/kg). Our results provide a comprehensive set of morphometric data for ostrich chicks as affected by the factors studied.

**Key words:** Crude Protein, stocking density, growth, body measurements, ostrich.

### INTRODUCTION

The fast increase in human population caused a continuous need for the increment of food resources, especially high-protein products like meat. This has increased per capita consumption of chicken, and thus, commercial farming has expanded to ostrich and it is increasing rapidly (Laudadio and Tufarelli 2011, Bouyeh et al. 2017). Recent

interest in ostrich farming has led to an increase in the demand for information about this bird and how to manage it in the commercial farms (Minka 2004, Cooper et al. 2008, El-Safty and Mahrose 2009, Mahrose et al. 2016). To maximize profit, the ostrich industry must focus on increasing chick survivability, maximizing growth and reducing costs associated with feeding (Cornetto et al. 2003, Bouyeh et al. 2017). The factors affecting growth in ostriches are similar to those affecting other avian species and include diet, rearing environment, genetic potential, management and health status. Literature on ostrich nutrition and available space

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is limited, particularly those pertaining to the early-life stage (Iji 2005, Mahrose et al. 2015, Sigolo et al. 2017, Vahabi-Asil et al. 2017).

Stocking density needed by ostrich chicks depends on the type of housing. Semi-intensive rearing of birds is the most widely used method and even during intensive keeping of ostriches in controlled environment houses it is advisable to let them out to minimize occurrence of leg problems (du Preez 1991). The aforementioned author added that the values of stocking density of broilers should not be directly applied to ostrich chicks. Providing adequate space to ostrich chicks could help diminish stress and consequently lead to improving survivability and growth rate (Cornetto et al. 2003). Ostrich chicks are raised under a wide range of stocking densities, ranging from 16 to 40 m<sup>2</sup> per bird (Verwoerd 1999).

However, the development of ostrich industry is hampered by inadequate knowledge of nutritional requirements of this species, particularly those pertaining to the early-life stage (Iji 2005). Nutrition is an important part of poultry and ratite management. So, knowledge of nutrient needs during the various stages of growth, development and production of the ostrich is vital (Cooper et al. 2005). Nutrition of ostrich chicks must be correct, as they are most vulnerable up to the age of 3 months (Cooper 2004). In order to increase profitability of ostriches, determination of nutrient requirements of ostriches is essential (Cilliers et al. 1998). The inclusion of protein in feeds needs to be optimized for optimum performance as well as to minimize wastage (Ahmed et al. 2011). Ostriches require rations with high protein content, which is an essential nutrient for optimum growth and development (Cooper 2004). Feeding costs are the largest expense in an ostrich production system, and protein is one of the most expensive components of the diet (Carstens et al. 2014). Diverse recommendations concerning the protein content in starter diets (14.6-22% CP) of ostriches have been reported. Most ratite growers

feed diets that contain 17-24% crude protein during brooding and growing (Cilliers 1998). The protein deficiency, caused by either one or more limiting amino acids or an overall inadequate consumption of protein, will result in decreases in parameters such as growth rate, N retention, feed consumption and utilization (Reda et al. 2015). However, an over-consumption of protein results in the catabolism of amino acids through deamination and excretion as uric acid, which is both energetically and economically inefficient or in severe cases, ammonia toxicity (Alagawany et al. 2016a, b). It is essential to try to meet the requirement of poultry as closely as possible in order to maximize production and profitability (Alagawany et al. 2014, Rehman et al. 2018).

The present study aimed at investigating the effects of stocking density and dietary crude protein levels on growth performance and body measurements of ostrich chicks during 2-10 weeks of age.

## MATERIALS AND METHODS

The present work was carried out at the Ostrich farm, Faculty of Agriculture, Zagazig University, Zagazig city, Egypt. All experimental procedures were carried out according to the Local Experimental Animal Care Committee, and approved by the ethics of the institutional committee of the Department of Poultry, Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

### BIRDS, EXPERIMENTAL DESIGN AND DIETS

Thirty-six African Black unsexed ostrich chicks were allotted into 6 groups (6 chicks per group; each group had three sub-groups of equal numbers; 2 birds each) in factorial arrangement (3×2) to investigate the influences of 3 dietary protein levels (180, 210 and 240 g/kg) and 2 levels of stocking density (4.5 and 3 m<sup>2</sup> per bird) on growth performance (body weight, body weight gain, feed consumption,

feed conversion ratio and protein efficiency ratio) of ostrich chicks during 2 to 10 weeks of age. In addition, body measurements (body height, neck length, neck diameter, thoracic girth, phalanges length, tarsometatarsus length, tarsometatarsus girth, tibiotarsus length and tibiotarsus girth) were measured at 6 and 10 weeks of age. Ingredients and composition of experimental diets of ostrich chicks are found in Table I. All diets were isocaloric.

#### MANAGEMENT

Unsexed ostrich chicks of 2 weeks of age were randomly divided into 6 groups (of equal average body weight). Each chick was identified by shank tag. Chicks were kept indoors until 4 weeks of age and after that, they were allowed to practice outdoors during midday and kept indoors at night. Chicks were exposed to 16:8 h light/dark cycle and light intensity for all groups ranged between

24 and 50 Lux. All chicks were kept under similar managerial and hygienic conditions during the experimental period. Food was provided *ad libitum* to all groups during the experimental period. Fresh water was made available at all times.

#### DATA COLLECTION AND MEASUREMENTS

All chicks were individually weighed using an electronic balance accurate to 5 g and body weight was recorded at 2, 6 and 10 weeks of age. Daily body weight gain was calculated as the difference between the two successive weights and divided by the number of days. Feed consumption was weekly recorded for each group, and calculated as gram diet per bird by dividing feed consumption of the group by the number of birds in this group. Feed conversion ratio (g feed /g gain) was calculated. Protein efficiency ratio was calculated by dividing daily weight gain by protein intake.

**TABLE I**  
**Ingredients and calculated analysis of ostrich chick diets.**

Ingredients (g/kg as fed basis)	Crude protein (g/kg diet)		
	180	210	240
Yellow Corn	377	438	462
Soybean meal 44 (%)	360	313	190
Gluten meal 62 (%)	26	0.0	20
Hay	72.5	94.0	200.0
Wheat bran	100.0	89.0	70.0
Molasses	8.5	12.5	9.5
Vit-min Premix <sup>#</sup>	12.5	10.0	8.0
DL Methionine	2.0	2.0	1.5
L-Lysine	4.0	4.0	1.5
Di Calcium phosphate	20.0	20.0	10.0
Limestone	15.0	15.0	25.0
NaCl	2.5	2.5	2.5
Calculated analysis (g/kg as fed basis)			
CP (g/kg)	180	210	240
MJ/kg	10.3	10.4	10.3

<sup>#</sup>Growth vitamin and Mineral premix, each 1 kg consists of: Vit A 12000,000 IU/kg; Vit D<sub>3</sub>, 2000,000 IU; Vit. E, 10,000 IU/kg as dl- $\alpha$ -tocopheryl acetate; Vit k<sub>3</sub> 2 g; Vit B<sub>1</sub>, 1000 mg ; Vit B<sub>2</sub>, 49g ; Vit B<sub>6</sub>, 105 g; Vit B<sub>12</sub>, 10 mg; Pantothenic acid, 10 g; Niacin, 20 g, Folic acid, 1000 mg; Biotin, 50 g; Choline Chloride, 500 mg, Fe, 30 g; Mn, 40 g; Cu, 3 g; Co, 200 mg; Si, 100 mg and Zn, 45 g.

Linear dimensions of the body (body height, neck length, neck diameter, thoracic girth, phalanges length, tarsometatarsus length, tarsometatarsus girth, tibiotarsus length and tibiotarsus girth) were taken twice during the experimental period (at 6 and 10 weeks of age) to the nearest 0.5 cm with dressmaker's flexible tape-measure and are described as follows; bird height was taken from claws to dorsal of the thorax. Thoracic girth was measured behind the shoulders at the notch in the junction between the cervical and thoracic vertebrae. Length of tibiotarsus was measured on the lateral side of the leg from the front of the patella to the back of the hock joint as described by Deeming et al. (1996). Tibiotarsus girth was taken from the mid. The length of the tarsometatarsus was measured on the caudal side of the leg from the back of the hock joint to the phalangeal joint. Tarsometatarsus girth was taken from the its mid.

#### STATISTICAL ANALYSIS

Data of the present study were statistically analyzed by ANOVA of 3×2 factorial design experiment. Differences between means were tested by Duncan's multiple range test at level of  $\alpha = 0.05$  (Duncan 1955). The statistical model used was:

$$Y_{ijk} = \mu + CP_i + SD_j + CPSD_{ij} + e_{ijk}$$

Where:  $Y_{ijk}$  = an observation,  $\mu$  = the overall mean,  $CP_i$  = fixed impact of crude protein levels,  $SD_j$  = fixed impact of stocking density,  $CPSD_{ij}$  = fixed impact of interaction between CP and SD levels and  $e_{ijk}$  = random error associated to each observation.

#### RESULTS

Results of live body weight and daily body weight gain as affected by dietary crude protein levels and stocking density are presented in Table II. It is obvious from the results that live body weight and daily body weight gain during the experimental

periods were insignificantly affected by dietary crude protein levels, stocking density and their interactions. Results affirmed the occurrence of insignificant differences in body weight at 2 weeks of age among the different groups, a finding that gives an idea about the accuracy in distributing chicks among the treated feeding groups without any bias.

Results in Table III revealed that dietary crude protein level, stocking density and their interactions did not significantly alter feed consumption, feed conversion ratio and protein efficiency ratio. However, the highest value of protein efficiency ratio (1.19), during 2-10 weeks of age, was observed in ostrich chicks fed diet containing 240 g/kg, followed by those fed 210 g/kg CP then those fed 180 g/kg CP (1.01). Also, birds fed diet containing 240 g/kg CP and kept at stocking density of 3 m<sup>2</sup> per bird had insignificantly the highest protein efficiency ratio in comparison to the other groups (Table III).

Table IV presents the effects of dietary protein levels, stocking density and their interactions on body measurements including body height, tibiotarsus length and tibiotarsus girth. It could be seen that each of shank girth and tibiotarsus length were decreased ( $P < 0.01$ ) with increasing dietary protein level. Where, the highest values of shank girth and tibiotarsus length (9.1 and 18.4 cm, respectively) were observed in chicks fed 180 g/kg dietary protein level. The other body measurements were not significantly affected due to dietary protein level. Stocking density did not change values of body measurements, except tibiotarsus length at 6 weeks of age, which was increased ( $P < 0.05$ ) in birds kept at 3 m<sup>2</sup>/ bird. Body height at 10 weeks of age was the exceptional measurement. It was significantly ( $P < 0.05$ ) affected by the interactions among dietary protein levels and stocking density. Birds kept at a lower density and fed higher levels of crude protein had the higher values of body height.

**TABLE II**  
**Live body weight and daily body weight gain of growing ostrich as affected by dietary crude protein levels, stocking density and their interactions.**

Items	Live body weight (g)			Daily body weight gain (g/d)			
	2 wks	6 wks	10 wks	2-6 wks	6-10 wks	2-10 wks	
CP level							
180	2961	6170 <sup>c</sup>	11263	114.6 <sup>c</sup>	181.9	148.3	
210	2662	6453 <sup>b</sup>	11240	135.4 <sup>b</sup>	171.0	153.2	
240	2797	7737 <sup>a</sup>	12921	176.5 <sup>a</sup>	185.1	180.8	
Stocking density (m <sup>2</sup> /bird)							
4.5	2800	6888	12049	146.0	184.4	165.2	
3	2814	6686	11566	138.3	174.3	156.3	
Interaction effect							
CP level	Stocking density						
180	4.5	2960	6517	11968	127.0	194.7	160.9
	3	2962	5824	10557	102.2	169.0	135.6
210	4.5	2744	6181	11737	122.8	198.4	160.6
	3	2580	6724	10743	148.0	143.5	145.8
240	4.5	2693	7964	12443	188.2	160.0	174.1
	3	2900	7510	13399	164.7	210.3	187.5
SEM	105.94	12.84	14.27	2.72	2.87	2.17	
Probabilities:							
CP level	0.527	0.021	0.100	0.036	0.850	0.148	
Stocking density	0.084	0.634	0.482	0.662	0.643	0.523	
CP× Stocking density	0.203	0.455	0.334	0.426	0.153	0.502	

Means in the same column within each classification bearing different letters are significantly different ( $P < 0.05$ ).

## DISCUSSION

Growth performance traits of ostrich chicks are important for their rearing under different farming conditions and assessing the performance of rearing practices. Results of the present work demonstrated that extra protein consumed by birds could not be productively utilized by ostrich chicks and were probably eliminated via fecal nitrogen as reported in previous publications (Ahmed et al. 2011, Mahrose et al. 2015). However, Bovera et al. (2011) claimed that feed containing 17% CP was optimum for ostrich chicks at 20 weeks of age and feeding growing ostriches on higher protein levels not only wasteful but also pollute the environment

through the excretion of more unutilized nitrogen (Abd El-Hack et al. 2017, 2018). Due to these explanations, growth rate of the ostriches appeared to be influenced by other environmental factors (Deeming and Ayres 1993), such as stocking density. In addition, Bunter (2002) demonstrated that variability in growth rates in ostrich chicks is attributed to general factors such as season, diet, aspects of social behavior and health. Ahmed et al. (2011) reported that ostrich chicks aged between 10 to 14 weeks of age and fed diets containing 22.5 and 17.5% CP insignificantly consumed more feed, grew better and were more efficient in converting feed to body weight than birds fed diet containing 12.5% CP. Carstens et al. (2014) found insignificant

**TABLE III**  
**Feed consumption, feed conversion ratio and protein efficiency of growing ostrich as affected by dietary crude protein levels, stocking density and their interactions.**

Items	Feed consumption (g)			Feed conversion ratio (g feed/g gain)			Protein efficiency ratio (Body weight gain/ protein intake)			
	2-6 wks	6-10 wks	2-10 wks	2-6 wks	6-10 wks	2-10 wks	2-6 wks	6-10 wks	2-10 wks	
CP level										
180	584.8	826.6	705.7	5.4	4.7	5.1	1.23	1.17	1.16	
210	538.5	702.6	620.6	4.5	4.4	4.4	1.14	1.18	1.18	
240	522.8	785.3	654.0	3.0	4.6	3.8	1.01	1.16	1.19	
Stocking density (m <sup>2</sup> /bird)										
4.5	539.2	834.8	687.0	4.2	4.8	4.5	1.08	1.16	1.18	
3	558.2	708.2	633.2	4.5	4.2	4.4	1.17	1.17	1.17	
Interaction effect										
CP level	Stocking density									
180	4.5	592.8	894.5	743.6	4.7	4.7	4.7	1.23	1.21	1.21
	3	576.8	758.8	667.8	6.2	4.6	5.4	1.24	1.13	1.11
210	4.5	487.0	760.3	623.6	4.8	4.2	4.5	1.23	1.23	1.24
	3	590.1	644.9	617.5	4.1	4.5	4.3	1.06	1.12	1.13
240	4.5	537.8	849.8	693.8	2.9	5.5	4.2	0.79	1.05	1.10
	3	507.7	720.8	614.3	3.1	3.6	3.4	1.22	1.27	1.28
SEM		15.73	21.92	13.23	0.41	0.49	0.35	0.31	0.26	0.26
Probabilities:										
CP level		1.643	10.736	9.920	0.060	0.919	0.089	0.403	0.990	0.968
Stocking density		0.428	32.419	11.722	0.670	0.291	0.754	0.525	0.891	0.948
CP × Stocking density		2.116	0.072	2.305	0.484	0.251	0.339	0.219	0.332	0.422

differences between the high (23.48% CP) and low (16.8% CP) diets on body weight gain during the first 7 weeks of age, insignificant differences between the high and medium (20.28% CP) diets on body weight gain during the first eleven weeks of age and insignificant differences between the medium and low diets on body weight gain during the first fourteen weeks of age. Our results are similar to those obtained by Brand et al. (2000) who concluded that dietary protein levels (13, 15 and 17%) had no effect on the growth performance of ostrich chicks during 16 to 44 weeks of age. Gandini and Burroughs (1986) showed comparable results, where ostrich chicks, aged up to 8 weeks of age, fed diets of different protein levels (14,

16, 18 and 20%), no differences were found in growth performance among diets with 16, 18 or 20% protein, while birds on these diets performed better compared to those on a 14% protein diet and those received 20% CP showed the superior feed conversion. Vahabi-Asil et al. (2017) assured that dietary protein level had a significant effect on body weight gain and feed conversion ratio of turkeys during the finisher phase.

In the present work, the best ratio of feed conversion (3.8 g feed / g gain) was seen in the group of chicks that fed on 180 g/kg CP diet during the whole period (2-10 weeks of age). The average of the feed conversion ratio from hatch to 9 months of ostrich age ranges from 3.6 to 3.9 (Bunter



**TABLE IV**  
**Body dimensions (cm) of growing ostrich as affected by dietary crude protein levels, stocking density and their interactions.**

	Body height		Neck length		Neck diameter		Thoracic girth		Phalanges length		Shank length		Shank girth		Tibiotarsus length		Tibiotarsus girth		
	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	6 wks	10 wks	
CP level																			
180	89.8	141.4	33.5	51.5	10.5	15.4	52.85	79.3	12.4	18.7	22.9	32.8	9.1 <sup>a</sup>	11.6	18.4 <sup>a</sup>	37.8	52.8	27.4	
210	77.7	146.0	29.5	52.0	9.8	14.5	51.4	86.3	10.9	16.8	21.0	34.0	7.5 <sup>c</sup>	12.3	10.6 <sup>c</sup>	37.8	51.4	27.5	
240	86.7	154.0	32.6	59.2	9.8	14.7	56.8	74.2	12.1	14.8	22.1	31.0	8.3 <sup>b</sup>	13.3	12.8 <sup>b</sup>	40.2	56.8	29.7	
Stocking density (m <sup>2</sup> /bird)																			
4.5	87.2	149.7	33.2	55.7	10.27	15.1	56.4	78.2	12.3	17.3	23.0	32.3	8.3	12.9	15.2	39.8	56.6	28.8	
3	82.2	144.68	30.5	52.8	9.9	14.6	50.7	81.6	11.3	16.2	20.9	32.8	8.3	11.9	12.6	37.3	50.7	27.5	
Interaction effect																			
CP level	Stocking density																		
180	4.5	94.5	132.5	35.5	51.0	10.5	15.5	54.5	73.0	13.5	19.0	24.3	32.0	9.3	12.0	20.0	36.0	54.0	28.0
	3	85.0	150.3	31.5	52.0	10.5	15.3	51.0	85.5	11.3	18.3	21.5	33.5	9.0	11.3	16.8	39.5	51.0	26.8
210	4.5	77.0	156.5	30.0	54.0	10.0	15.5	53.8	91.0	10.8	16.5	21.1	35.0	7.1	12.5	11.5	41.0	53.8	26.5
	3	78.3	135.5	29.0	50.0	9.7	13.5	49.0	81.5	11.0	17.0	20.8	33.0	7.8	12.0	9.7	34.5	49.0	28.5
240	4.5	90.0	160.0	34.2	62.0	10.0	14.3	61.7	70.7	12.5	16.3	23.7	30.0	8.5	14.3	14.2	42.3	61.7	32.0
	3	83.3	148.0	31.0	56.3	9.5	15.0	52.0	77.7	11.7	13.3	20.5	32.0	8.2	12.3	11.5	38.0	52.0	27.3
SEM		2.62	3.50	0.99	1.52	0.20	0.32	1.70	2.83	0.44	1.03	0.90	0.95	0.20	0.38	0.99	1.17	1.70	1.00
Probabilities																			
CP level	0.178	0.253	0.252	0.078	0.336	0.517	0.404	0.226	0.384	0.116	0.737	0.514	0.000	0.179	0.000	0.624	0.404	0.624	
Stocking density	0.354	0.408	0.187	0.319	0.534	0.427	0.097	0.548	0.316	0.441	0.313	0.814	0.862	0.151	0.046	0.309	0.097	0.550	
CP × Stocking density	0.679	0.050	0.812	0.607	0.893	0.266	0.730	0.262	0.542	0.582	0.815	0.700	0.176	0.659	0.884	0.216	0.730	0.463	

Means in the same column within each classification bearing different letters are significantly different ( $P < 0.05$  or  $0.01$ ).

2002), so our results are in that range. Ahmed et al. (2011) indicated that ostrich chicks during 10-14 weeks of age fed diets containing 22.5 or 17.5% CP consumed more feed and were more efficient in converting feed than birds fed diets containing 12.5% CP. However, the later author added that the differences between the two diets contained 22.5 and 17.5% CP were inconsistent and not significant on feed consumption and feed conversion ratio. The inability of the digestive tract of the ostrich chicks to secrete trypsin immediately after hatching constitutes a major difference between this species and broiler chickens (Iji 2005). This suggests that utilization of dietary protein during early life will be less efficient in the ostrich than in poultry. Commercial diets for ostriches are still based on poultry formulations, but it is unlikely that the high levels of dietary protein used in broiler chicken diets will be efficiently utilized by the neonatal ostrich. The activity of amylase is low and remains relatively unchanged from hatch until 72 days of age (Mahrose et al. 2015).

Amado et al. (2011) indicated that ostrich chicks walked and ran more than when they were older. In turn, it means that ostrich chicks may need more space to show their behavior and grow better. Space requirements for ostriches vary slightly according to type of accommodation. However, from a welfare point of view, 0.5 m<sup>2</sup> of floor space per bird during the first three weeks is generally recommended, increasing to 0.7 m<sup>2</sup> up to five weeks. From about five weeks of age (depending on weather conditions), the chicks should be allowed out for about one hour daily (Shanawany and Dingle 1999). In this regard, in the study carried out by Degen et al. (1991), ostrich chicks were kept at stocking density of 1 bird/m<sup>2</sup>. Overcrowding during the brooding and rearing stages can lead to slow growth rates. In an experiment conducted by Cornetto et al. (2003) on ostrich chicks aged between 21 to 98 days, they found that there were significant differences in body weight gain only

during 28 to 56 days of age, where ostrich chicks kept in the lower stocking density (33.5 m<sup>2</sup>/bird) had the higher body weight gain. However, they did not find significant changes in feed conversion ratio due to stocking density, but they concluded that the stocking density of 16 m<sup>2</sup> per bird was found to maximize chicks' performance. In our study, feed conversion ratios were higher than what was reported by the latter author. In line, Bouyeh et al. (2017) found no significant impact for stocking density on productive and reproductive performance of ostriches.

Measuring body dimensions could be a useful tool to estimate body weight and the area of the skin (Bezuidenhout and Schalkwyk 1996, Deeming et al. 1996, Ali 2004) that is a way to predict profit at marketing and to solve one of the main problems in ostrich trading, which is the cheating in age or weight of chicks in some areas. Body condition of ostriches is very important to avoid obesity and loss of weight is an important indicator of malnutrition (Deeming et al. 1996). The same author added that the body measurements are important in aiding the calculation of dosage of medications. The later authors added that tibiotarsus length in growing ostriches up to sub-adults (less than two years of age) ranged from 10 to 64 cm. Mushi et al. (1998) pointed out that the average of body height rapidly increased reaching 134 cm in the 16<sup>th</sup> week, and this is very close to what is reported in the present study with taking age into consideration. Body measurements in the present study are higher than those reported by Ali (2004) at 75 days of age.

The results of the present study indicated that ostrich chicks (during 2-10 weeks of age) could grow on diets containing low levels of CP (180-210 g/kg). The present study suggested the needs for further research on the protein requirements for ostrich. Also, our results imply that space availability for ostrich chicks during 2-10 weeks of age can influence their performance. Results of the present work provide a comprehensive set of



morphometric data for ostrich chicks during 2-10 weeks of age as affected by dietary protein level, stocking density and their interactions, which could be useful for the breeders.

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#### AUTHOR CONTRIBUTIONS

Khalid Mahrose and Mohamed Abd El-Hack designed the study plan, collected literature, and drafted the manuscript. Shymaa Amer helped in conducting research work. Khalid Mahrose provided technical help in the write-up of this manuscript. Khalid Mahrose and Mohamed Abd El-Hack reviewed and performed the final check. All the authors read and approved the final manuscript.

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