Effect of dietary calcium and phosphorus levels on growth, carcass characteristics and liver and kidney functions of growing Egyptian geese

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ABSTRACT The present study investigated the effect of different dietary levels of calcium (**Ca**) and non-phytate phosphorus (**P**) on the growth performance, carcass characteristics, and blood components of growing geese. A total of 120, 4-wk-old Egyptian goslings with similar body weights were randomly distributed to four groups in a 2 × 2 factorial arrangement, which included 2 levels of Ca (0.85% and 0.70%) and 2 levels of non-phytate P (0.45% and 0.35%). Each group was subdivided into 6 replicates of five birds. The experiment lasted 8 wk, from 4 to 12 wk of age. Results show that dietary Ca level had no significant effect on any of the studied growth performance traits over the full experimental period. Dietary P level also had no significant impact on these traits, with the exception of daily body weight gain and feed conversion ratio at 8 to 12 wk of age; these improved significantly with the low P diet. Geese received a diet containing 0.70% Ca + 0.45% P had the lowest body weight values at 12 wk of age and the lowest daily body weight gain, and feed intake at 8 to 12 weeks of age. While, the lowest value of feed conversion ratio was recorded in geese fed low level of Ca with low level of P (0.70% Ca + 0.35% P). There were no significant effects of the different dietary levels of Ca, P, or their interaction on all studied carcass parameters. Low dietary Ca level significantly increased the plasma levels of total protein, albumin, alanine transaminase (**ALT**), aspartate transaminase (**AST**), and creatinine and significantly decreased the plasma levels of Ca and P. Different dietary P levels had no significant effect on plasma levels of albumin, AST, ALT, ALP, and urea, whereas the 0.35% P-based diet significantly decreased the plasma contents of total protein, creatinine, Ca, and P. Plasma levels of albumin, creatinine, urea, Ca, and P were not affected by an interaction between Ca and P. Diets containing 0.70% Ca and 0.45% P lead to the highest plasma values for total protein, ALT, AST, and ALP compared with the other dietary Ca and P combinations. In conclusion, dietary Ca and P levels can be simultaneously reduced without negative impacts on growth performance, carcass characteristics, or blood biochemical components. We advise to avoid increasing the dietary Ca: P ratio, as it leads to negative effects on growth performance and blood biochemistry in growing geese. So, the findings of the current study recommended the low levels of Ca (0.70%) and non-phytate P (0.35%) for the performance of Egyptian geese during the fattening period.

Key words: geese, calcium, non-phytate phosphorus, performance, blood

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INTRODUCTION

Geese are a type of herbivorous waterfowl, and they have a rapid growth rate compared with domesticated birds reared for meat production. They consume large amounts of green grass, clover, and some plants. When economically feasible, these growing rates and dietary concerns must be accommodated in feeding programs (Arroyo et al., 2017; Abou-Kassem et al., 2019; Alagawany et al., 2020a,b). In terms of overall production and marketing, waterfowl production has remained relatively static; because there are currently very few internationally recognized commercial breeders, performance has become more standardized, specialized, and widespread (Zhu et al., 2011; Ashour et al., 2020). Because of the absence of feeding standards for geese, farmers must base feed allowances on personal experience and feeding standards for chickens (Arroyo et al., 2012). An investigation of the nutritional requirements of geese is necessary to maximize productivity. Achieving standard mineral requirements is important for the growth, production, and reproduction of geese; however, to date, there are no clear standard mineral requirements for geese in Egypt.

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Calcium (**Ca**) has important biological functions and must be provided in adequate amounts. Inadequate Ca intake may affect bone mineral content, muscle function, and the functions of other minerals (Peters and Mahan, 2008). Information on the effect of different Ca levels is very limited. Tancharoenrat and Ravindran (2014) found that a higher concentration of dietary Ca reduced the performance and the utilization of phosphorus (**P**), Ca, nitrogen, and energy in broilers. Increased dietary Ca concentrations are often associated with reduced Ca availability (Gautier et al., 2017) and increased P, magnesium, manganese, and zinc excretion (Wilkinson et al., 2014); these increased Ca concentrations also impair the process of digestion through the formation of insoluble salts, which reduce nutrient utilization, including that of P (Tamim et al., 2004). Hamdi et al. (2015) reported that a lower Ca concentration is desirable as it leads to better performance in starting broilers.

As an essential nutrient, P plays a key role in bone mineralization in poultry (Berndt and Kumar, 2009). Recently, the broiler nonphytate P (**NPP**) requirements recommended by the National Research Council (NRC, 1994) have been revaluated to reduce the excretion of P (Jiang et al., 2016; Liu et al., 2017). A high content of phytase P in bird corn–soybean diets limits the bioavailability of Ca, P, and N (Nelson et al., 1968).

The dietary needs of Ca and NPP are interdependent (Yan et al., 2005; Gautier et al., 2017). An imbalanced Ca: P ratio leads to the formation of insoluble complexes, which lowers the utilization of minerals and energy, and consequently, decreases growth performance (Plumstead et al., 2008). Wilkinson et al. (2014) stated that the Ca: NPP ratio is more important than the absolute individual dietary concentrations of Ca and NPP. Geese requirements for Ca and NPP, as recommended by the NRC (1994) based on research from more than 6 decades ago (Aitken et al., 1958), might not be applicable to modern classes of geese and their diets. Thus, the objective of our study was to evaluate the effect of varying dietary calcium and non-phytate phosphorus levels on the growth performance, carcass characteristics, and blood biochemistry parameters of growing Egyptian geese.

MATERIALS AND METHODS

Birds, Husbandry, Experimental Design, and Diets

The present study was conducted at the waterfowl Research Farm, Poultry Department, College of Agriculture, University of Zagazig, Egypt. All experimental procedures were carried out in accordance with the Local Experimental Animal Care Committee, which approved the study. Geese were cared for using husbandry guidelines derived from Zagazig University's standard operating procedures.

When goslings arrived, the temperature at geese level directly under the source of heat was 36 to 37°C which decreased to 32 to 33°C at the end of the first week and to 23 to 25°C by the end of the second week. After this age, no further additional heat source was required. At the first 3 d, the birds were subjected to 24 h of light per day and then to 12 h of light and 12 h of darkness per day for the remainder of the experimental period. All geese were reared under the same managerial and medical conditions; mash feed and fresh water were consistently available for all birds.

A total of 120, 4-wk-old Egyptian goslings with similar body weights (1300+164 g) were randomly distributed into 4 groups. Each group contained 30 birds and was subdivided into 6 replicates of 5 birds. The experiment lasted for 8 wk, from 4 to 12 wk of age. During the experimental period, the geese were kept in appropriate pens, under the same conditions. Each replicate was housed in one pen in-floor system for 8 wk (experimental period). The space of each pen was 2 m^2 which provides 0.4 m^2 per one goose.

Experimental groups were randomly arranged in a 2 × 2 factorial arrangement, which included 2 levels of dietary Ca (0.85% and 0.70%) and 2 levels of dietary non-phytate P (0.45% and 0.35%) to study the effects of Ca, non-phytate P and their interaction on growth, carcass traits, blood chemistry of growing geese. The experimental diets were formulated to be isocaloric and isonitrogenous and were supplemented with amino acids and other nutrients to meet the nutritional requirements of growing geese proposed by the NRC (1994), as shown in Table 1. The proximate analyses of the experimental diets were carried out according to AOAC (2003) for determination of crude protein, ether extract, crude fiber, Ca and total phosphorus.

Data Collection

Birds were weighed individually at 4, 8, and 12 wkof age. Feed intake (**FI**) and mortality were recorded daily; the mortality rate was zero for all treatments, so these data are not presented. Daily body weight gain (**DBWG**) and feed conversion ratio (**FCR**) were calculated.

At the end of the experiment, 24 birds (6 from each group) were randomly selected, fasted overnight, weighed, and slaughtered for carcass evaluations and blood sampling. Carcass weight (i.e., main body, liver, heart, gizzard, and other edible parts) was determined according to the methodology proposed by Blasco and Ouhayoun (1996). Carcass weights were calculated as a percentage of the pre-slaughter live body weight of the bird. The following equation was used: dressed weight = (carcass weight + giblets weight) / live body weight.

During slaughter, blood samples were collected from 6 birds per treatment into heparinized tubes that were closed with rubber stoppers. To evaluate biochemical parameters, blood samples were centrifuged (G force rate = 2146.56 × *g*) for 900 s. The plasma levels of total protein (g/dL), albumin (g/dL), alanine transaminase (**ALT**; IU/L), aspartate transaminase (**AST**; IU/L), alkaline phosphatase (**ALP**) (U/L), creatinine (mg/

Table 1. Composition and chemical analysis of the basal diets as fed.

	Ca 0.85%		Ca 0.7%	
	P 0.45%	P 0.35%	P 0.45%	P 0.35%
Ingredients (g/kg diet)				
Yellow corn	66.00	66.2	66.00	66.00
Soybean meal (44%)	18.34	18.4	18.26	18.34
Gluten meal (60%)	4.55	4.49	4.40	4.50
Wheat bran	7.50	7.50	8.13	8.13
Di Calcium phosphate	1.80	1.25	1.8	1.25
Limestone	0.85	1.20	0.45	0.82
Vit-min premix[1]	0.30	0.30	0.30	0.30
NaCl	0.30	0.30	0.30	0.30
DL Methionine	0.12	0.12	0.12	0.12
L-Lysine HCl	0.24	0.24	0.24	0.24
Total	100	100	100	100
Calculated analysis (%)[2]				
Crude protein %	18.03	18.04	18.00	18.10
ME kcal/kg diet	2902	2907	2902	2906
Calcium %	0.85	0.85	0.70	0.70
Non-phytate P	0.45	0.35	0.45	0.35
Lysine %	1.00	1.00	1.00	1.00
Methionine+ Cysteine %	0.75	0.75	0.75	0.75
Crude fibre %	3.62	3.63	3.66	3.68
Determined analysis (%)				
Crude protein	17.92	17.92	17.90	17.99
Calcium	0.88	0.87	0.73	0.73
Phosphorous (total)	0.74	0.65	0.75	0.65
Crude fiber	3.60	3.60	3.66	3.66
Ether extract	3.52	3.53	3.54	3.54

[1]Growth vitamin and Mineral premix each 2.5 kg consists of: Vit A 12000, 000 IU; Vit D3, 2000, 000 IU; Vit. E. 10g; Vit k3 2 g; Vit B1, 1000 mg; Vit B2, 49g; Vit B6, 105 g; Vit B12, 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.
[2]Calculated according to NRC (1994).

dL), urea (mg/dL), Ca (mg/dL), and P (mg/dL) were determined spectrophotometrically using commercial kits from the Biodiagnostic Company (Giza, Egypt).

Statistical Analysis

All of the statistical analyses were performed using the SPSS (2008). Data were statistically analyzed as a 2 × 2 factorial arrangement (Snedecor and Cochran, 1982), using the following model:

$$Y_{ijk} = \mu + A_i + S_j + AS_{ij} + e_{ijk},$$

Where Y_{ijk} is an observation, μ is the overall mean, Ai is the effect of the Ca level (I = 1−2), S_j is the effect of the P level (j = 1−2), AS_ji is the interaction between the levels of Ca and P, and e_{ijk} is the experimental random error. A post-hoc Tukey's test was conducted to detect differences between treatments. All differences were significant at $P < 0.05$.

RESULTS AND DISCUSSION

Growth Performance

The effects of varying dietary Ca and non-phytate P levels on the growth performance of growing geese are presented in Table 2. Dietary Ca level had no significant ($P > 0.05$) effect on average BW, DBWG, FI, and FCR during all the experimental periods (4−8, 8−12, and 4 −12 wk of age). Dietary P level had no significant impact on these traits across all ages, with the exception of DBWG and FCR at 8 to 12 wk of age, which improved significantly (P = 0.031 and 0.048, respectively) with the low level of non-phytate P (0.35%) compared with the high level (0.45%). Our results are consistent with those of Rao et al. (2006) and Wang (2011); they fed Shitou geese diets with different levels of Ca (0.65%, 0.95%, and 1.25%) and available phosphorus (0.40%, 0.60%, and 0.80%) and recorded no significant impact of Ca levels on DBWG, FI, and FCR, and a low level of P (0.40%) improved these traits to a degree comparable with that of higher levels (0.60% and 0.80%) at 1 to 21 days of age. An opposite result was obtained by Wenli et al. (2005), who found that the DBWG, FI, and FCR of Wulong geese fed 0.65% Ca diets were better than those who had been fed diets with higher Ca levels (0.75%, 0.85%, and 0.95%). The same authors added that different levels of dietary phosphorus

Table 2. Average body weight (BW) and daily body weight gain (DBWG) performance of growing geese as affected by the effect of calcium, non-phytate phosphorus levels and their interaction[1].

	Average BW/bird (g)			Average daily BWG, g		
Items	4wk	8 wks	12 wks	4−8 wks	8−12 wks	4−12 wks
Calcium levels (%)						
0.85 %	1311 ± 136	2554 ± 256	3262 ± 341	44.38 ± 5.44	25.27 ± 2.85	34.83 ± 3.87
0.70 %	1289 ± 197	2446 ± 327	3139 ± 443	41.32 ± 4.00	24.74 ± 7.05	33.03 ± 5.22
Non-phytate P levels (%)						
0.45 %	1329 ± 179	2490 ± 273	3118 ± 372	41.48 ± 3.60	22.43 ± 4.53	31.95 ± 3.91
0.35 %	1271 ± 154	2510 ± 322	3282 ± 409	44.23 ± 5.81	27.59 ± 4.65	35.91 ± 4.42
Interaction						
Ca P						
0.85% 0.45%	1343 ± 165	2552 ± 237	3275 ± 344[a]	43.19 ± 2.81	25.81 ± 3.56[a]	34.50 ± 3.13
0.85% 0.35%	1280 ± 94.4	2556 ± 283	3249 ± 349[a]	45.58 ± 7.86	24.73 ± 2.60[ab]	35.16 ± 5.23
0.70% 0.45%	1315 ± 196	2429 ± 300	2962 ± 340[b]	39.77 ± 3.97	19.05 ± 2.10[b]	29.41 ± 2.99
0.70% 0.35%	1263 ± 201	2464 ± 361	3316 ± 472[a]	42.88 ± 4.13	30.44 ± 4.77[a]	36.66 ± 4.45
P-value						
Ca effect	0.612	0.167	0.217	0.326	0.796	0.466
P effect	0.194	0.802	0.101	0.375	0.031	0.130
Interaction effect	0.905	0.844	0.049	0.906	0.013	0.198

[ab]Means within the same column with different superscripts are different ($P < 0.05$).
[1]The number of replicate for each treatment was 6.

Table 3. Feed intake (FI) and feed conversion ratio (FCR) of growing geese as affected by the effect of calcium, non-phytate phosphorus levels and their interaction[1].

Items	FI (g)			FCR (g feed/ g gain)		
	4–8 wks	8–12 wks	4–12 wks	4–8 wks	8–12 wks	4–12 wks
Calcium levels (%)						
0.85 %	126.1 ± 2.18	138.2 ± 3.84	132.1 ± 2.01	2.875 ± 0.35	5.537 ± 0.72	3.838 ± 0.47
0.70 %	120.0 ± 8.24	135.8 ± 7.98	127.9 ± 7.33	2.931 ± 0.41	5.809 ± 1.39	3.942 ± 0.60
Non-phytate P levels (%)						
0.45 %	120.8 ± 7.32	135.0 ± 5.26	127.9 ± 5.51	2.935 ± 0.37	6.196 ± 1.06	4.049 ± 0.49
0.35 %	125.2 ± 5.44	139.0 ± 6.69	132.1 ± 5.26	2.871 ± 0.39	5.150 ± 0.84	3.731 ± 0.52
Interaction						
Ca P						
0.85% 0.45%	124.3 ± 1.74	139.7 ± 2.05[ab]	132.0 ± 1.83	2.888 ± 0.22	5.493 ± 0.88[ab]	3.851 ± 0.40
0.85% 0.35%	127.8 ± 0.24	136.8 ± 5.17[ab]	132.3 ± 2.59	2.861 ± 0.50	5.581 ± 0.72[ab]	3.824 ± 0.62
0.70% 0.45%	117.2 ± 9.65	130.4 ± 0.82[b]	123.8 ± 4.73	2.981 ± 0.54	6.899 ± 0.74[a]	4.247 ± 0.57
0.70% 0.35%	122.7 ± 7.39	141.2 ± 8.42[a]	131.9 ± 7.90	2.881 ± 0.35	4.719 ± 0.84[b]	3.637 ± 0.53
P-value						
Ca effect	0.123	0.427	0.167	0.823	0.572	0.745
P effect	0.246	0.211	0.173	0.799	0.048	0.334
Interaction effect	0.783	0.048	0.201	0.885	0.040	0.374

[ab]Means within the same column with different superscripts are different ($P < 0.05$).
[1]The number of replicate for each treatment was 6.

(0.3% vs. 0.4%) had a significant impact on DBWG and FI, whereas FCR was not significantly affected. Additionally, Hamdi et al. (2015) reported that higher Ca levels (0.9%) had negative effects on FI and BWG, whereas lower Ca concentrations were desirable as they promoted better broiler performance. Zhu et al. (2018) reported that increasing the level of dietary P provided to Lion-head goslings significantly impaired growth performance traits, including BW, BWG, and FI. In another study, reducing dietary P levels did not significantly affect the BW, WG, FI, and FCR of broiler chickens from 1 to 42 days of age (Farhadi et al., 2017).

In the current study, other than average **BW** at 12 wk of age, as well as DBWG, feed consumption, and FCR at 8 to 12 wk of age, there were no significant effects of an interaction between dietary Ca and P levels on growth parameters (Tables 2 and 3). The lowest BW at 12 wk of age and DBWG, and FI at 8 to 12 wk of age were recorded in birds that had been given low level of Ca with high level of P (0.70% Ca + 0.45% P). While, the lowest value of FCR was recorded in geese fed low level of Ca with low level of P (0.70% Ca + 0.35% P). These results may be a response to an imbalanced Ca: P ratio, leading to the formation of insoluble complexes, which lowered the utilization of minerals and energy and consequently decreased growth performance (Plumstead et al., 2008).

Wilkinson et al. (2014) stated that the Ca: NPP ratio is more important than the absolute individual dietary concentrations of Ca and NPP. Our findings are similar to those obtained by Zhu et al. (2018), who reported that decreasing the dietary Ca: NPP ratio for Lion-head goslings significantly impaired BW, BWG, and FI. Wang (2011) recorded no significant changes in the BWG, FI, and FCR of Shitou geese fed diets containing different levels of Ca (0.65%, 0.95%, and 1.25%) and available phosphorus from 29 to 70 days of age. Mohamed et al. (2020) showed that BW, BWG, FI, and FCR were not significantly affected by restricting dietary Ca and NPP by up to 50% of the levels recommended by the NRC (1994) during the starter and grower periods. In contrast to our findings, Imari et al. (2020) found that restricting the dietary Ca and available P (to 10%−30% of the recommended levels) during the starter period of broilers significantly decreased BW, BWG, and FI, whereas FCR was not affected; BWG, FI, and FCR were not significantly affected during the finisher and post-starter periods.

Dietary phosphorus is not fully digested and utilized by different poultry species due to the insufficient secretion of the endogenous phosphatases in their digestive system. There are some evidences that broiler chickens may develop adaptive mechanisms when subjected to deficiency of available phosphorus through early age (Ashwell and Angel, 2010; Proszkowiec-Weglarz and Angel, 2013). Feeding chickens with phosphorus-deficient rations for 90 h post-hatch resulted in improved dietary utilization of phosphorus later in life (Ashwell and Angel, 2010). Then, starting diets low in phosphorus element may develop specific adaptive changes in birds that help them use P more efficiently throughout the growing and finishing stages. Rousseau et al. (2016) stated that broiler chickens are able to adapt to the early life deficiency of dietary calcium and phosphorus by improving efficiency of digestion in the next ages, and the level of compensation for bone mineralization and growth rate depends on the amount of calcium and phosphorus in the post-starter rations. On the other hand, El-Faham et al. (2019) noted that broilers fed diets containing half their Ca and P requirements had worse BWG, FI, and FCR. In contrast, Hassanabadi et al. (2007) found that feeding broilers diets containing 80% of the recommended levels of Ca and P significantly improved BW, BWG, and FCR.

Carcass Characteristics

The data in Table 4 summarize the impact of different levels of Ca and non-phytate P on Egyptian goose

Table 4. Carcass traits of growing geese as affected by the effect of calcium, non-phytate phosphorus levels and their interaction[1].

Items		Carcass %	Dressing %	Liver %	Heart %	Gizzard %	Giblets %	Spleen %	Fat %	Thigh %	Breast %
Calcium levels (%)											
0.85 %		65.00 ± 0.88	72.60 ± 1.20	2.95 ± 0.37	0.71± 0.07	3.94 ± 0.34	7.60 ± 0.54	0.10 ± 0.02	2.17 ± 0.25	25.96 ± 0.89	36.87 ± 1.47
0.70 %		65.57 ± 1.46	73.17 ± 1.64	3.01 ± 0.28	0.68± 0.08	3.90 ± 0.46	7.60 ± 0.70	0.10 ± 0.01	2.01 ± 0.26	25.38 ± 0.90	38.18 ± 1.68
Non-phytate P levels (%)											
0.45 %		65.01 ± 1.10	72.85 ± 1.46	3.15 ± 0.25	0.72 ± 0.09	3.97 ± 0.42	7.84± 0.57	0.11 ± 0.01	2.08 ± 0.25	25.26 ± 1.02	37.67 ± 1.81
0.35 %		65.56 ± 1.31	72.92 ± 1.47	2.81 ± 0.30	0.68 ± 0.06	3.86 ± 0.37	7.36 ± 0.56	0.09 ± 0.02	2.11± 0.29	26.07 ± 0.60	37.38 ± 1.64
Interaction											
Ca	P										
0.85%	0.45%	64.98 ± 0.89	72.84 ± 0.68	3.17± 0.21	0.73± 0.09	3.95± 0.44	7.86± 0.21	0.11± 0.01	2.08± 0.25	25.50± 0.98	37.39± 2.00
0.85%	0.35%	65.03 ± 1.08	72.36± 1.72	2.72± 0.39	0.69± 0.06	3.92± 0.30	7.33± 0.69	0.09± 0.02	2.26± 0.27	26.42± 0.61	36.34± 0.78
0.70%	0.45%	65.04 ± 1.49	72.86 ± 2.21	3.12 ± 0.34	0.70 ± 0.10	3.991 ± 0.50	7.82 ± 0.87	0.10 ± 0.01	2.07 ± 0.30	25.02 ± 1.22	37.94 ± 1.99
0.70%	0.35%	66.09 ± 1.50	73.48 ± 1.24	2.91 ± 0.23	0.67 ± 0.06	3.808 ± 0.50	7.38 ± 0.56	0.09 ± 0.01	1.95 ± 0.25	25.73 ± 0.39	38.41 ± 1.71
P-value											
Ca effect		0.464	0.549	0.703	0.593	0.880	0.993	0.562	0.323	0.278	0.218
P effect		0.472	0.941	0.088	0.427	0.686	0.222	0.120	0.852	0.141	0.773
Interaction effect		0.508	0.560	0.507	0.992	0.774	0.907	0.873	0.372	0.834	0.459

[1]The number of replicate for each treatment was 6.

carcass characteristics at 12 wk of age. There were no significant effects of the different dietary levels of Ca, non-phytate P, and their interaction on all carcass parameters (i.e., carcass, dressing, liver, heart, gizzard, giblets, spleen, fat, thigh, breast, and head). Consistent with the present findings, Imari et al. (2020) found that restricting dietary calcium and available phosphorus by 10% to 30% of the recommended levels had no significant effects on the carcass traits and internal organs of broiler chickens at 42 days of age. Han et al. (2015) reported that dietary NPP levels had no significant impact on the carcass traits of broilers. Additionally, Akter et al. (2016) noted that the internal organ relative weights of broiler chicks were not impacted by reducing dietary Ca from 10 to 6 g/kg and dietary NPP from 4 to 3 g/kg. Tizziani et al. (2019) demonstrated that the carcass yield of broiler chickens was not influenced by reducing Ca levels up to 30% of the requirements. In contrast, El-Faham et al. (2019) found that decreasing the dietary Ca and available P to a level equivalent to half of the requirements significantly decreased the dressing and carcass yield in broilers. Han et al. (2016) reported that a lower Ca: NPP ratio resulted in a lower carcass yield in broilers.

Blood Biochemical Parameters

The data in Table 5 demonstrate the influence of the different dietary levels of Ca and non-phytate P on the blood parameters of geese at 12 wk of age. ALP activity, and urea level in plasma were not significantly ($P > 0.05$) influenced by the different dietary levels of Ca. The highest values for total protein ($P < 0.001$), albumin ($P = 0.011$), ALT (P < 0.001), AST ($P = 0.005$), and creatinine ($P < 0.036$) were found in geese fed a low Ca diet, but the highest ($P < 0.001$) values of Ca and P were found in the plasma from geese fed a high Ca diet.

Changes to the level of dietary P had no significant effect on the plasma levels of albumin ($P = 0.614$), AST ($P = 0.069$), ALT ($P = 0.186$), ALP ($P = 0.897$), and urea ($P = 0.243$). Growing geese feed the 0.35% P-based diet had significantly lower plasma levels of total protein ($P < 0.001$), creatinine (P = 0.009), Ca ($P = 0.001$), and P ($P = 0.006$).

In this study, the plasma levels of Ca and P seem to reflect the levels present in the experimental diets. Unaltered serum ALP activity indicates that lower levels of dietary Ca and P had no detrimental effects on bones (Gonzalez-Quintela et al., 2008). Comparable results were obtained by Bar et al. (2003), who reported that reducing dietary Ca from 10.3 to 1.9 g/kg at 1−11 days of age led to a significant decrease in serum Ca levels in fast-growing chickens. Kheiri and Rahmani (2006) reported that serum concentrations of Ca and P were not influenced by reducing the P levels in broiler diets. Fallah et al. (2019) noted adverse effects on serum P concentrations when dietary Ca levels increased from 0.4% to 1.3%, whereas serum levels of Ca and total proteins were not significantly impacted by these changes.

With respect to the effect of the interaction between the levels of dietary Ca and P (Table 5), plasma levels of albumin, creatinine, urea, Ca, and P did not differ ($P > 0.05$) at different combinations. Diets containing 0.70% Ca and 0.45% P led to the highest plasma values for total protein ($P < 0.001$), ALT ($P < 0.001$), AST ($P < 0.023$), and ALP ($P < 0.028$), compared with the other combinations. Birds fed a diet with high levels of Ca and P (0.85% Ca and 0.45% P) had the lowest ALP activity in plasma. Increased levels of AST, ALT, and ALP are indicators of liver and bone malfunction due to a high Ca: NPP ratio. Our results are similar to those found by Hassanabadi et al. (2007), who noted that feeding broilers diets containing 80% of the recommended levels of Ca and P increased serum ALP activity and decreased serum P concentration, with no significant effect on serum Ca concentration. Imari et al. (2020) noted that Ca, P, and ALP levels in the blood serum of broilers were not significantly influenced by a restriction of dietary Ca and available P at 10 and 42 days of age. Conversely, Mohamed et al. (2020) showed that plasma concentrations of Ca, AST, and ALT were not significantly affected by a dietary Ca and NPP restriction of up to 50% of the recommended levels, whereas plasma P concentrations were significantly decreased.

Table 5. Blood biochemical parameters of growing geese as affected by the effect of calcium, non-phytate phosphorus levels and their interaction[1].

Items	Total protein (g/dL)	Albumin (g/dL)	ALT (U/L)[2]	AST (U/L)[2]	ALP (U/L)[2]	Creatinine (mg/dL)	Urea (mg/dL)	Ca (mg/dL)[2]	P (mg/dL)[2]
Calcium levels (%)									
0.85 %	4.235 ± 0.10	1.485 ± 0.11	20.72 ± 3.44	51.80 ± 8.16	116.0 ± 32.3	0.565 ± 0.09	18.38 ± 2.25	11.80 ± 1.00	7.776 ± 0.82
0.70 %	5.183 ± 0.76	1.663 ± 0.07	29.30 ± 6.69	68.20 ± 11.5	134.0 ± 30.0	0.642 ± 0.07	19.62 ± 1.27	8.200 ± 1.20	5.903 ± 0.84
Non-phytate P levels (%)									
0.45 %	5.038 ± 0.91	1.560 ± 0.15	26.38 ± 9.47	63.11 ± 16.6	124.0 ± 37.2	0.656 ± 0.04	18.36 ± 2.33	10.88 ± 1.83	7.445 ± 1.15
0.35 %	4.380 ± 0.17	1.588 ± 0.11	23.64 ± 2.56	56.89 ± 7.76	126.0 ± 27.5	0.551 ± 0.09	19.64 ± 1.10	9.117 ± 2.23	6.234 ± 1.13
Interaction									
Ca	P								
0.85% 0.45%	4.210 ± 0.05[c]	1.437 ± 0.07	17.82 ± 0.98[c]	48.88 ± 7.14[b]	95.46 ± 12.0[b]	0.637 ± 0.04	17.19 ± 2.66	11.08 ± 0.91	7.149 ± 0.54
0.85% 0.35%	4.260 ± 0.14[c]	1.533 ± 0.13	23.63 ± 1.83[b]	54.71 ± 9.49[b]	136.6 ± 34.6[ab]	0.493 ± 0.04	19.57 ± 1.18	12.52 ± 0.36	8.404 ± 0.45
0.70% 0.45%	5.867 ± 0.13[a]	1.683 ± 0.10	34.95 ± 1.77[a]	77.34 ± 5.89[a]	152.6 ± 29.3[a]	0.675 ± 0.04	19.53 ± 1.54	7.151 ± 0.19	5.319 ± 0.63
0.70% 0.35%	4.500 ± 0.11[b]	1.643 ± 0.06	23.65 ± 3.62[b]	59.07 ± 6.80[b]	115.3 ± 18.7[ab]	0.609 ± 0.08	19.72 ± 1.28	9.249 ± 0.50	6.486 ± 0.60
P-value									
Ca effect	<0.001	0.011	<0.001	0.005	0.254	0.036	0.258	<0.001	<0.001
P effect	<0.001	0.614	0.069	0.186	0.897	0.009	0.243	0.001	0.006
Interaction effect	<0.001	0.241	<0.001	0.023	0.028	0.232	0.315	0.333	0.895

[a-c]Means within the same column with different superscripts are different ($P < 0.05$).
[1]The number of replicate for each treatment was 6.
[2]ALT: alanine transaminase; AST: aspartate transaminase; ALP: alkaline phosphatase; Ca: calcium; P: phosphorus

CONCLUSIONS

Results suggest that the dietary calcium and phosphorus levels for Egyptian geese could be simultaneously reduced without negative impacts on their growth performance, carcass characteristics, or blood biochemical components. We advise to avoid increasing the dietary Ca: P ratio, because this leads to harmful effects on the growth performance and blood biochemistry of growing Egyptian geese.

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DISCLOSURES

No potential conflicts of interest declared.

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