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ANIMAL PRODUCTION

Different calcium sources on the productive performance and bone quality of meat quail

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ABSTRACT: *This study was developed to examine the effect of using charru mussel-, maçunim- and oyster-shell meals as calcium sources on the productive performance, carcass yield and bone parameters of meat quail. A total of 250 one-day-old non-sexed European quail were used. The birds were distributed into five treatments (calcium sources: calcitic lime, calcium carbonate, charru mussel shell meal, maçunim shell meal or oyster shell meal) in a completely randomized design with five replicates and ten birds per experimental unit. Feed intake, weight gain and feed conversion were evaluated from one to 35 days. At 35 days, two birds with the average weight of the plot were slaughtered per plot and used for analysis of carcass yield and bone parameters. There were no significant differences (P > 0.05) in feed intake, weight gain, feed conversion, carcass yield or tibia dry matter content, ash content and strength. The charru mussel-, maçunim- and oyster-shell meals can be used as calcium sources in the diet of European quail without affecting their productive performance, carcass yield or bone mineralization.*
Key words: *european quail, mollusk shells, organic calcium sources.*

Diferentes fontes de cálcio sob o desempenho produtivo e qualidade óssea de codornas de corte

RESUMO: *Objetivou-se avaliar o efeito da utilização das farinhas de conchas de sururu, maçunim e ostra como fontes de cálcio sobre o desempenho produtivo, rendimento de carcaça e parâmetros ósseos de codornas de corte. Foram utilizadas 250 codornas europeias, não sexadas, com um dia de idade. As aves foram distribuídas em delineamento inteiramente casualizado, constituído por cinco fontes de cálcio (calcário calcítico, carbonato de cálcio, farinha de conchas de sururu, farinha de conchas de maçunim e farinha de conchas de ostras), com cinco repetições e dez aves por unidade experimental. Foram avaliados o consumo de ração, ganho de peso e conversão alimentar no período de um a 35 dias. Aos 35 dias, duas aves de peso médio de cada parcela foram abatidas e utilizadas para as análises de rendimento de carcaça e parâmetros ósseos. Não foram observadas diferenças significativas (P > 0,05) para os dados de consumo de ração, ganho de peso, conversão alimentar, rendimento de carcaça, matéria seca, cinzas e resistência óssea de tíbias. As farinhas de conchas de sururu, maçunim e ostra podem ser utilizadas na alimentação de codornas europeias, como fontes de cálcio, sem afetar o desempenho produtivo, rendimento de carcaça e a mineralização óssea das aves.*
Palavras-chave: *codornas europeias, conchas de moluscos, fontes orgânicas de cálcio.*

INTRODUCTION

Quail farming is a promising activity due to the rapid growth, early development and high egg productivity of the species, as well as low investment and rapid financial return (PASTORE et al., 2012; BARROS JÚNIOR et al., 2020). Like other animals, to express their maximum productive potential, quail must have their nutritional requirements met, especially with respect to minerals.

Calcium is a macromineral that participates in important functions of the body of birds, e.g., bone formation and maintenance, blood coagulation, muscle contraction, transmission of nerve stimuli, activation of enzymes in various metabolic pathways, among others (REZVANI et al., 2019). For European quail, SILVA et al. (2012) recommended 0.850% calcium in the starter phase (1-21 days) and 0.700% in the grower phase (22-42 days). Supplementation is necessary to meet

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the nutritional requirements of calcium, since non-ruminant diets, formulated with vegetable ingredients, contain insufficient calcium levels.

According to SANTANA et al. (2018), the most widely used sources of calcium in animal feed are of geological or industrial origin, such as calcitic limestone. However, its extraction causes environmental problems, as it is a non-renewable resource. Conversely, organic sources offer the great advantage of being renewable sources. Studies showed that organic sources of calcium, such as shells, algae and eggshells, have a better absorption rate and greater biological potency as compared with inorganic minerals (LEÃO et al., 2020; RAJKUMAR et al., 2017).

LEÃO et al. (2020) stated that the disposal of shells of bivalve mollusks on the edge of the lagoon in the state of Alagoas, Brazil, is done inadequately. These can be considered by-products from the processing of maçunim (*Anomalocardia brasiliana*), oysters (*Crassostrea brasiliana*) and charru mussel (*Mytella charruana*), which are part of the local cuisine. Due to the availability of these shells in the region and their high calcium content, there has been a growing interest in using them in animal feed.

This study was developed to investigate the effect of using charru mussel-, maçunim- and oyster-shell meals as calcium sources on the productive performance, carcass yield and bone parameters of meat quail.

MATERIALS AND METHODS

The experiment was carried out in the quail farming section at CECA/UFAL, located in Rio Largo - AL, Brazil. A total of 250 one-day-old, non-sexed European quail were used. The birds were housed according to their initial average weight (8.95±1.58 g) in galvanized-wire battery cages during the experimental period of one to 35 days of age. Each cage was equipped with a heating source, a tube drinker, a trough feeder and excreta collection trays. The quail were distributed into five treatments in a completely randomized design with five replicates of ten birds, totaling 25 experimental units.

The experimental diets were formulated following the recommendations of SILVA & COSTA (2009), with the evaluated sources replacing the inert from the basal diet (BD) (Table 1). Thus, the experimental diets were composed as follows: calcitic limestone (CLS) = BD + CLS; calcium carbonate (CCB) = BD + CCB; charru mussel shell meal (CSM) = BD + CSM; maçunim shell meal (MSM) = BD + MSM; and oyster shell meal (OSM) = BD + OSM (Table 2). The calcium sources originated from the coastal region of the state of Alagoas and were acquired ready for the birds to consume. Dicalcium phosphate (24.5% Ca and 18.5% P), commonly used as a source of calcium and phosphorus in diets, was replaced by monoammonium phosphate so that its calcitic content would not interfere with the results.

Climatic variables were monitored daily, at 08h00 and 16h00. The following mean values were recorded: maximum temperature - 29.4 °C, minimum temperature - 27.01 °C, relative humidity - 80% and black globe humidity index - 77.68 (calculated according to the formula proposed by BUFFINGTON et al., 1981).

Feed intake, weight gain and feed conversion were evaluated from one to 35 days of age. To this end, the birds, feed and orts were weighed weekly to calculate the performance indices.

At the end of the experimental period, all birds were weighed and two medium-weight quail (one male and one female) from each experimental unit were selected and identified. After fasting for six hours, the birds were weighed, stunned by electronarcosis, bled, scalded and plucked.

Subsequently, the carcasses were eviscerated and carcass yield was determined relative to the live animal weight and cut yields relative to the carcass weight. The following parameters were evaluated: absolute (g) and relative (%) weights of the carcass, major cuts (breast, drumsticks and thighs) and edible offal (heart, liver and gizzard).

To determine the bone's breaking strength, dry matter (DM) content and ash content at 35 days, the selected birds had their legs collected and the tibiae removed. The right tibia was used for the breaking strength test and the left for DM and ash content analyses.

For the analysis of breaking strength, the unprocessed bones (right tibiae) were placed in a controlled testing machine (Shimadzu model AG-X 100kN), which records the resistance of materials to bending. The bones were placed in a horizontal position on two supports, and a pressure force was applied to their center. Breaking strength was defined as the maximum amount of force (kgf) applied to the bones at the breakpoint.

The left tibiae of the birds were defatted using petroleum ether in a Soxhlet apparatus, at a temperature of 40 to 60 ºC for 8 h. Then, analyses of

Table 1 - Proximate composition of basal diets for meat quail, according to the requirements of the birds for each age.

Ingredient (%)	---Bird age (days)---	
	1 to 21	21 to 35
Maize grain	48.527	55.915
Soybean meal - 45% CP	44.928	37.242
Soybean oil	2.299	3.182
Inert	2.000	2.000
Monoammonium phosphate	0.988	0.712
Common salt	0.370	0.318
DL-methionine	0.228	0.209
L-threonine	0.242	0.000
L-lysine	0.168	0.220
Vitamin supplement[1]	0.100	0.100
Mineral supplement[2]	0.050	0.050
Zinc bacitracin	0.050	0.000
Anticoccidial	0.050	0.000
Total	100.000	100.000
---Calculated composition---		
Calcium (%)	0.167	0.143
ME Poultry (kcal/kg)	2900	3050
Available phosphorus (%)	0.380	0.300
Dig. lysine Poultry (%)	1.370	1.230
Dig. met. + cys. Poultry (%)	0.889	0.808
Dig. met. Poultry (%)	0.550	0.500
Crude protein (%)	25.00	22.00
Sodium (%)	0.170	0.150
Dig. threonine Poultry (%)	1.040	0.723

[1]Composition per kilogram of vitamin premix product: vit. A - 10,000,000 IU; vit. D3 - 2,000,000 IU; vit. E - 30,000 mg/kg; vit. K - 2,880 mg/kg; thiamine (B1) - 3,500 mg/kg; riboflavin (B2) - 9,600 mg/kg; pyridoxine (B6) - 5,000 mg/kg; cyanocobalamin (B12) - 19,200 mcg/kg; folic acid - 1,600 mg/kg; pantothenic acid - 25,000 mg/kg; niacin - 67,200 mg/kg; biotin - 80,000 mcg/kg.

[2]Composition per kilogram of mineral premix product: manganese - 150,000 ppm; zinc - 140,000 ppm; iron - 100,000 ppm; copper - 16,000 ppm; iodine – 1,500 ppm; selenium - 600 ppm.

DM and ash contents were carried out according to the methodology of SILVA & QUEIROZ (2006), with results expressed relative to the dry- and defatted-bone weight.

Statistical analyses were performed using R CORE TEAM (2016) software and the data were subjected to the normality test (Shapiro-Wilk) and analysis of variance (ANOVA).

RESULTS AND DISCUSSION

In the phases from 1 to 21, 22 to 35 and 1 to 35 days of age, there was no significant difference ($P > 0.05$) for the variables of feed intake, weight gain or feed conversion (Table 3). According to the results, the use of the organic calcium sources tested had no adverse effect that could negatively interfere with the performance of the quail. Thus, the evaluated sources met the metabolic requirements of the birds at all stages.

These results agree with those described by LEÃO et al. (2020), who reported no differences in the performance of meat quail fed diets containing charru mussel shell, maçunim shell meal and oyster shell meal. REZVANI et al. (2019) evaluated the use of eggshells and oyster shells in

Table 2 - Amount of inert replaced with calcium sources in the basal diet.

Calcium source[1]	Calcium content[2]	--------------------------Amount in the diet (%)------------------------	
		1 to 21	22 to 35
CLS	37.70	1.81	1.41
CCB	38.00	1.80	1.40
CSM	36.01	1.90	1.48
MSM	35.33	1.93	1.51
OSM	34.93	1.95	1.52

[1]CLS - calcitic limestone; CCB - calcium carbonate; CSM - charru mussel shell meal; MSM - maçunim shell meal; OSM - oyster shell meal.

the diets of broilers and detected no differences in productive performance.

Calcium ingested via diet is absorbed and used according to the metabolic requirements of the animal. However, the bioavailable fraction of this mineral varies according to the source used as well as with intestinal pH, Ca:P ratio, vitamin D, among others, which can interfere with its absorption (SILVA et al., 2009).

MELO & MOURA (2009) reported that the solubility of calcium sources is directly related to the bioavailability and intestinal absorption of calcium, with organic sources having greater solubility as compared with inorganic sources (rocks). Thus, according to LEÃO et al. (2020), charru mussel-, maçunim- and oyster-shell meals have high relative calcium bioavailability, which may prove the good utilization of these sources by quail.

The alternative calcium sources did not influence the absolute weight at slaughter and the absolute and relative weights of the birds' carcass, cuts and edible offal (P > 0.05) (Table 4). These findings confirmed the birds' performance results

Table 3 - Feed intake (FI), weight gain (WG) and feed conversion (FC) of meat quail fed diets with different calcium sources, per phase.

Parameter	---------------------------Calcium source[1]---------------------------						
	CLS	CCB	CSM	MSM	OSM	P-value*	CV (%)
------------1 to 21 days of age------------							
FI	284.86	287.40	282.96	283.65	285.91	0.79	2.15
WG	148.04	150.80	147.21	146.65	148.30	0.43	2.42
FC	1.92	1.91	1.92	1.93	1.93	0.56	1.39
------------22 to 35 days of age------------							
FI	397.04	403.29	386.80	399.75	394.43	0.55	3.97
WG	92.96	92.51	90.54	91.95	92.09	0.98	7.35
FC	4.28	4.36	4.28	4.40	4.29	0.94	6.94
------------1 to 35 days of age------------							
FI	681.90	690.69	669.76	683.40	680.34	0.51	2.68
WG	241.00	243.31	237.75	238.60	240.38	0.84	3.39
FC	2.83	2.84	2.82	2.87	2.83	0.91	3.01

[1]CLS - calcitic limestone; CCB - calcium carbonate; CSM - charru mussel shell meal; MSM - maçunim shell meal; OSM - oyster shell meal. *Not significant (P > 0.05).

Table 4 - Absolute (g) and relative (%) weights of carcass, cuts and edible offal of mixed meat quail fed different calcium sources, at 35 days of age.

Variable	Calcium source[1]					P-value*	CV%
Absolute weight (g)	CLS	CCB	CSM	MSM	OSM		
Before slaughter	248.80	248.40	242.70	248.80	245.80	0.62	2.96
Carcass	188.49	184.33	180.01	186.46	185.38	0.30	3.33
Breast	76.85	74.89	74.24	78.14	76.85	0.28	4.02
Legs	38.45	40.60	38.84	39.26	40.35	0.26	4.47
Liver	4.73	4.45	4.35	4.45	4.45	0.44	7.31
Heart	2.23	2.12	2.13	2.26	2.31	0.31	7.52
Gizzard	4.45	4.40	4.29	4.45	4.33	0.89	7.03
Relative weight (%)							
Carcass	75.76	74.23	74.19	74.94	75.39	0.49	2.22
Breast	40.78	40.63	41.24	41.90	41.44	0.10	1.89
Legs	20.39	22.02	21.58	21.07	21.77	0.06	4.07
Liver	2.51	2.41	2.42	2.38	2.40	0.83	7.59
Heart	1.18	1.15	1.18	1.20	1.24	0.39	6.27
Gizzard	2.36	2.38	2.38	2.38	2.33	0.98	6.87

[1]CLS - calcitic limestone; CCB - calcium carbonate; CSM - charru mussel shell meal; MSM - maçunim shell meal; OSM - oyster shell meal. *Not significant (P > 0.05).

described above. The organic calcium sources used in this study provided results similar to those obtained with calcitic limestone and calcium carbonate in terms of performance and carcass yield.

There was no difference (P > 0.05) in the DM, ash or breaking strength of the bone of male and female European quail at 35 days of age (Table 5). These results indicated that the charru mussel-, maçunim-

Table 5 - Dry matter (DM) and ash contents and breaking strength (BS) of the tibiae of European quail at 35 days of age.

Bone parameter	Calcium source[1]					P-value*	CV%
	CLS	CCB	CSM	MSM	OSM		
Dry matter (%)							
Males	82.55	83.87	83.42	79.22	83.78	0.45	5.36
Females	70.08	70.52	73.02	70.26	76.50	0.21	7.10
Ash (%, DM basis)							
Males	51.97	56.10	53.72	53.03	52.24	0.41	6.85
Females	53.85	55.28	52.67	51.53	53.18	0.64	7.08
BS (kgf)							
Males	6.00	6.34	6.13	6.86	6.91	0.34	13.21
Females	5.99	6.77	6.77	6.44	6.79	0.27	10.02

[1]CLS - calcitic limestone; CCB - calcium carbonate; CSM - charru mussel shell meal; MSM - maçunim shell meal; OSM - oyster shell meal. *Not significant (P > 0.05).

and oyster-shell meals can be used effectively, at 100% inclusion, as calcium sources for European quail from 1 to 35 days of age without compromising their development.

LEÃO et al. (2020) did not find differences in the bone ash content of meat quail fed diets with charru mussel-, maçunim- and oyster-shell meals as calcium sources. Skeletal strength and hardness depend on the normal concentration of calcium, and bone mineralization only occurs when there is a balance between the plasma concentrations of calcium and phosphorus (VELLASCO et al., 2015).

The skeleton acts as a reservoir for calcium, so when serum calcium concentrations decrease, the mineral is mobilized from the bones to increase blood calcium levels. When this happens, the bones are more fragile causing the symptoms of calcium deficiency in developing birds include growth retardation, reduced feed intake, bone fragility and deformation, in addition to reduced bone ash and calcium content (VELLASCO et al., 2015).

The tested sources provided effective bone calcification, as all treatments induced similar results regarding bone ash deposition and strength, as well as performance and carcass yield. Despite their low cost, traditionally used sources cause environmental degradation upon extraction. Therefore, the use of organic sources such as those evaluated in this study emerges as an environmentally sustainable alternative, since they can be used in animal feed instead of being improperly disposed of.

CONCLUSION

Charru mussel-, maçunim- and oyster-shell meals can be used as calcium sources in the diet of European quail from 1 to 35 days of age without affecting their productive performance, carcass yield or bone mineralization.

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DECLARATION OF CONFLICT OF INTEREST

We have no conflicts of interest to declare.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript. All authors reviewed the manuscript critically and approved the final version.

ETHICS AND BIOSAFETY COMMITTEE

All procedures in this study were approved by the Ethics Committee on Animal Use at UFAL (approval no. 62/2017).

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