An Acad Bras Cienc (2023) 95(2): e20201688 DOI 10.1590/0001-3765202320201688
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

ANIMAL SCIENCE

Industrial egg residue as a calcium source in broiler feed: digestibility and growth performance

CLAUDIO NOVACK, MARCEL M. BOIAGO, ALINE ZAMPAR, MAURICIO BARRETA, ROSILENE OLIVEIRA, EDUARDO ROSCAMP, JÉSSICA D. DILKIN, TIAGO G. PETROLLI, DENISE N. ARAUJO, FERNANDO C. TAVERNARI, MARCOS T. LOPES & ALEKSANDRO S. DA SILVA

Abstract: Industrial egg residue (IER) possesses substantial concentrations of calcium and crude protein. The objective of this study was to measure the digestibility and performance of broilers when IER was added to the feed. Four treatments were tested, which caused increasing replacement of calcitic limestone by IER (0, 35, 70 and 100%) during a 42-day production cycle. First, total bird excreta were collected from broilers with and without IER, and we determined dry matter digestibility, apparent metabolizable energy (AME), calcium, and nitrogen retention. The IER presented 7.5% of crude protein, 31% of calcium, 209 kcal/kg of AME and the digestibility coefficients for dry matter, crude protein, and calcium were calculated at 83.95%, 86.20%, and 67%, respectively. After the digestibility test, the effects of IER on performance, carcass and meat yield were evaluated. No significant differences between the treatments were found in terms of performance (weight gain, feed conversion, consumption, and mortality), and no differences were found in terms of carcass or meat yield. A linear decrease in the percentage of abdominal fat was observed with increasing inclusion of IER in feed. These findings suggest that IER can totally replace limestone (calcium carbonate) in broiler diets.

Key words: Alternative ingredients, animal nutrition, digestibility, sustainability.

INTRODUCTION

With each passing year, production of broilers becomes more efficient with respect to performance. To achieve this end, nutrition research is carried, especially with respect to re-use of alternative ingredients that are typically industrial waste products. This is because these products have high levels of nitrogen and energy that help to reduce formulation costs (Garcia Jr 2010). The worldwide feed industry uses primarily corn and soybean meal; however, these ingredients are increasingly scarce and costly, making feed more expensive. Products such as animal meal are widely used to feed non-ruminant animals. In addition to having good nutritional value, these products minimize the environmental impact generated by slaughterhouses.

Industrial egg residue (IER) presents a possible alternative for bird feed, because the industrialization of eggs is a segment that grows yearly because of the numerous benefits attributable to the process, including longer product life, easy transportation and storage, among others. This industrialization generates a large volume of waste in the form of egg shells, with approximately 5.92 million tons of this material generated worldwide each year, most of which is used as organic fertilizer or is disposed of in landfills (Oliviera et al. 2009). IER originates from the breaking of eggs to separate albumen and yolk, which are then processed. In addition to its peel and membranes (internal and external), IER contains a considerable amount of albumen, which is rich in protein of high biological value. In the eggshell, calcium occurs in the form of calcium carbonate ($CaCO_3$), which represents about 94% of this structure (Murakami et al. 2007). Generally, calcium in poultry feed is derived from inorganic sources, including calcitic limestone and dicalcium phosphate, both of which come from rocks and are found in large quantities naturally, in addition to being relatively inexpensive (Araujo et al. 2008, Melo & Moura 2009). The calcium found in egg shells has greater solubility than calcitic limestone and dicalcium phosphate (Melo et al. 2006).

As long as it is correctly processed to avoid possible spread of pathogens, IER is a viable potential alternative ingredient for poultry feed. Production costs are low and its nutritional composition is compelling. Our hypothesis is that IER could be a source of calcium that could replace the calcitic limestone (CL) currently used in animal feed, as well as a form of protein supplementation due to albumen residues. Therefore, the objective of this study was to measure the digestibility and performance in broilers when IER is added to bird feed to partially or totally replace CL.

MATERIALS AND METHODS

Ethics committee

This project was approved by the Committee for the Use of Animals in Research (CEUA) of the Universidade do Estado de Santa Catarina (UDESC) under protocol number 1435300517. It complies with the rules issued by the National Council for Control of Animal Experimentation (CONCEA).

Experiment location and study stage

The research was carried out in the poultry sector of the Animal Science Department/*UDESC Oeste*, in the city of Chapecó-SC. The study was carried out in two stages. In the first, a digestibility test was conducted; the second was an evaluation of growth performance in male broilers raised to 42 days of age.

Industrial egg residue (IER)

The IER was obtained from an industrial egg pasteurization plant located in the municipality of Chapecó, SC and was processed (dehydrated and ground) in the animal nutrition laboratory of UDESC. The residue was dehydrated in a forced-air chamber at 55 ºC until constant weight was obtained. Subsequently, it was ground in a hammer-type mill with 1-mm pores. To measure the contents of dry matter, mineral matter, crude protein, ethereal extract, calcium and phosphorus, it were used methodologies described by Silva & Queiroz (2012). Crude energy was measured using a calorimetric pump (Model IKA C200®).

Total bacterial counts (TBC), total coliforms (TC), *Salmonella* spp. and *Escherichia coli* were measured in fresh eggshells and IER. The total bacterial counts were performed according to the Normative Instruction (Number 62 of 26 August 2003) from the Ministry of Agriculture, Livestock and Supply (Brazil). Quantifications of *Salmonella, E. coli* and total coliforms were made using 3M™ Petrifilm Plates. The numbers of colony forming unit (CFU) were evaluated after 48 h incubation of samples at 37 ºC.

In the microbiological analysis of fresh (without processing) eggshells, it were found

7.95 x 10^5 CFU/g, 4.69 x 10^4 CFU/g and 2.14 x 10^4 CFU/g of TBC, TC and *E. coli*, respectively. In the IER, TC and *E. coli* were not found; however, the TBC count was 3.9 x 10^2 CFU/g. *Salmonella* spp. were not identified in any samples.

Digestibility tests

For the digestibility tests, the methodology of the total collection of excreta from birds was used, described by Sakomura & Rostagno (2007). We used 60 1-day-old Cobb male broilers, distributed in a completely randomized experimental design of two treatments, with six repetitions per treatment and five birds per repetition. The birds were housed in 12 cages, where they received water and feed at will throughout the experiment.

The Control treatment consisted of reference feed (Table I), formulated based on corn, soybean meal and calcitic limestone. The test treatment used 70% of the feed used in the control treatment and the other 30% of the diet

Table I. Proximate and calculated composition of the reference diet in digestibility tests.

Ingredient	Inclusion (%)
Corn	55.6
Soy flour 45%	37.87
Soybean oil	2.5
Bicalcium phosphate	1.64
Calcitic calcitic limestone	1.11
Common salt	0.48
L-Lysine	0.35
DL Methionine	0.27
L- Threonine	0.06
Premix vitamin[1]	0.10
Premix mineral[2]	0.10
Calculated Composition	
Metabolizable energy (Kcal/kg)	2950
Crude protein (%)	21.5
Calcium (%)	0.92
Available phosphate (%)	0.42
Digestible lysine (%)	1.35
Digestible methionine (%)	0.55
Digestible methionine + cysteine (%)	0.85
Digestible threonine (%)	0.80
Digestible tryptophan (%)	0.23
Sodium (%)	0.21

[1] Minimum guarantee levels of the vitamin premix per Kg of the product: vitamin A (5000000 IU); vitamin D3 (1000000 IU); vitamin E (15,000 IU); Vitamin K3 (1500 mg); vitamin B1 (1500 mg); vitamin B2 (3000 mg); vitamin B6 (2000 mg); vitamin B12 (7000 mcg); folic acid (500 mg); nicotinic acid (15 g); pantothenic acid (7000 mcg); choline (80 g); biotin (100 mg); maximum humidity: (40 g); maximum mineral matter: (500 g).[2] Minimum guarantee levels of the mineral premix per Kg of the product: copper (10 g); iron (50 g); iodine (1000 mcg); manganese (80 g); selenium (300 mg); zinc (70 g); maximum humidity: (20 g); maximum mineral matter (980 g).

was IER. The experiment lasted eight days: four days for adaptation to experimental diets and four days for collection of excreta, as described by Barreta et al. (2021).

The collection of excreta occurred at an interval of 12 hours. The collected material was packed in plastic bags, properly identified and immediately frozen. At the end of the experimental period, the amount of feed consumed and the total amount of excreta produced were determined per repetition. To determine the dry matter of the excreta, samples were thawed, collected per repetition, homogenized, weighed and placed in a forced ventilation oven at a temperature of 55 ºC for 72 hours.

After pre-drying, the samples were ground and placed in plastic containers for further analysis of dry matter, crude energy, calcium and nitrogen. Samples of the two feeds were collected at the beginning of the test to determine the percentages of dry matter, crude protein, ether extract, calcium, phosphorus and ash, in addition to the gross energy (kcal/kg), according to the methodologies described by Silva & Queiroz (2012).

To obtain the apparent metabolizable energy and the coefficients, the following formulas were used:

AME feed Reference = (GE ing - GE exc) / DM ing

AME Test Ration = (E ing - GE exc) / DM ing

A MEfeed = aME ref + (aME test – aME ref) / g of the ingredient per g of feed.

where: AME= apparent metabolizable energy; GE ing. = Gross energy ingested;

GE exc. = Gross energy excreted; DM ing. = Ingested dry matter

AME ref. = Apparent metabolizable energy of the reference diet

Test AME = Apparent metabolizable energy of the test feed.

In turn, the digestibility coefficients were calculated according to the following formulas:

$$CPDC_{\text{basal feed}} = (\text{CP ing} - \text{CP exc}) / \text{CP ing.}$$

$$CPDC_{\text{ingredient}} = CPDC_{\text{basal feed}} + (CPDC_{\text{test feed}} - CPDC_{\text{basal feed}}) / \% \text{ in.}$$

where: CPDC = Crude Protein Digestibility Coefficient

CP ing. = Crude protein ingested; CP exc. = Crude protein excreted

% ing. = Percentage of inclusion of the ingredient.

NOTE: The values of % ing. were calculated considering the actual proportion of inclusion of the same.

Performance test

For the performance test, 320 1-day-old Cobb male broilers were used. The study was conducted in an experimental poultry house divided into 1.8 m² pens equipped with tubular feeders and nipple drinkers. The birds were distributed in a completely randomized design with four treatments, four repetitions per treatment and 20 birds per repetition. At the beginning of the experiment, the birds were weighed and allocated based on the average weight, such that all boxes were weighed within the 80% homogeneity range.

Each treatment involved experimental feed (Tables II and III). The calculations for isoproteic nutritional composition were based on the Brazilian Tables for Poultry and Swine (Rostagno

Table II. Proximate and calculated compositions of the experimental diets of the pre-initial (PI – 1 to 7 days) and initial (I – 8 to 21 days) phases used in performance tests.

	PI	I	PI	I	PI	I	PI	I
Ingredients	**T0**		**T35**		**T70**		**T100**	
Corn	50.05	52.43	50.19	52.57	50.35	52.76	50.51	52.86
Soy flour 45 %	41.78	38.68	41.67	38.59	41.55	38.46	41.44	38.36
Soybean oil	3.35	4.37	3.29	4.32	3.23	4.25	3.17	4.20
L-lysine	0.06	0.01	0.06	0.01	0.06	0.01	0.07	0.02
DL-methionine	0.34	0.38	0.34	0.38	0.34	0.38	0.34	0.38
L-threonine	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
NaCl	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Bicacalcium phos.	1.50	1.26	1.50	1.26	1.50	1.26	1.50	1.26
IER	0.00	0.00	0.49	0.45	0.97	0.94	1.43	1.39
Calcitic limestone	1.39	1.34	0.92	0.89	0.45	0.40	0.00	0.00
Premix vit. and mineral*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100	100	100	100	100	100	100	100
CALCULATED								
CP (%)	22.4	21.2	22.4	21.2	22.4	21.2	22.4	21.2
ME (kcal/kg)	2960	3050	2960	3050	2960	3050	2960	3050
Ca (%)	0.92	0.841	0.92	0.841	0.92	0.841	0.92	0.841
Available P (%)	0.47	0.35	0.47	0.35	0.47	0.35	0.47	0.35
Digestible lysine (%)	1.324	1.217	1.324	1.217	1.324	1.217	1.324	1.217
Digestible met. (%)	0.516	0.475	0.516	0.475	0.516	0.475	0.516	0.475
Dig. met.+ cys, (%)	0.953	0.876	0.953	0.876	0.953	0.876	0.953	0.876
Digestible threonine (%)	0.861	0.791	0.861	0.791	0.861	0.791	0.861	0.791
Digestible tryp. (%)	0.22	0.207	0.22	0.207	0.22	0.207	0.22	0.207
Sodium (%)	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21

*** Folic Acid (minimum) 75.00 mg/kg; Pantothenic acid (minimum) 1,000.00 mg/kg; Beta-xylanase (minimum) 800,000.00 U/kg; Copper (minimum) 630.00 g/kg; Hill (minimum) 34.80 g/kg; Iron (minimum) 5,250.00 mg/kg; Phytase (minimum) 50,000.00 PTU/kg; Iodine (minimum) 126.00 mg/kg; Lysine (minimum) 108.20 g/kg; Manganese (minimum) 7,000.00 mg/kg; Methionine (minimum) 329.30 g/kg; Niacin (minimum) 4,000.00 mg/kg; Selenium (minimum) 30.00 mg/kg; Threonine (minimum) 69.80 g/kg; Vitamin A (minimum) 1,000,000.00 IU/kg; Vitamin B1 (minimum) 300.00 mg/kg; Vitamin B12 (minimum) 1,800.00 mcg/kg; Vitamin B2 (minimum) 600.00 mg/kg; Vitamin B6 (minimum) 325.00 mg/kg; Vitamin D3 (minimum) 250,000.00 IU/kg; Vitamin E (minimum) 2,000.00 IU/kg; Vitamin K (minimum) 250.00 mg/kg; Zinc (minimum) 6,300.00 mg/kg; nicarbazine 5,000.00 mg/kg; narasine 5,000.00 mg/kg; tylosine 5,500.00 mg/kg.**

2017). The treatments consisted of partial or total replacement of the calcitic limestone with IER in the proportions of 35%, 70%, and 100%, so as to provide isonutritive feed. A control treatment was used consisting of reference feed, that is, with only calcitic limestone.

Water and feed were provided *ad libitum* throughout the 42-day experimental period, with water being provided in pressure bowls for the first few days and feed in nursery tubular feeders. Subsequently, adult nipple drinkers were used. At the end of each breeding phase (21, 35 and 42 days), weighing of the birds and

Table III. Proximate and calculated compositions of the experimental diets of the growth (G - 22 to 35 days) and final (F - 36 to 42 days) phases used in performance tests.

	G	F	G	F	G	F	G	F
Ingredients	**T0**		**T35**		**T70**		**T100**	
Corn	56.25	60.70	56.40	60.85	56.53	60.98	56.64	61.09
Soy flour 45 %	34.54	30.59	34.44	30.49	34.35	30.40	34.25	30.30
Soybean oil	5.18	5.06	5.13	5.01	5.09	4.97	5.04	4.92
L-lysine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DL-methionine	0.29	0.27	0.29	0.27	0.29	0.27	0.29	0.27
L-threonine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NaCl	0.45	0.43	0.45	0.43	0.45	0.43	0.45	0.43
Bicalcium P	1.03	0.69	1.03	0.69	1.03	0.69	1.03	0.69
IER	0.00	0.00	0.44	0.44	0.88	0.88	1.30	1.30
Calcitic limestone	1.26	1.26	0.82	0.82	0.38	0.38	0.00	0.00
Premix vit. and mineral*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100	100	100	100	100	100	100	100
CALCULATED								
CP (%)	19.80	18.40	19.8	18.40	19.8	18.40	19.8	18.40
ME (kcal/kg)	3150	3200	3150	3200	3150	3200	3150	3200
Ca (%)	0.76	0.66	0.76	0.663	0.76	0.663	0.76	0.663
Available P (%)	0.35	0.31	0.35	0.309	0.35	0.309	0.35	0.309
Digestible lysine (%)	1.13	1.09	1.13	1.09	1.13	1.09	1.13	1.09
Digestible methionine (%)	0.45	0.74	0.45	0.74	0.45	0.74	0.45	0.74
Digestible Met.+Cys. (%)	0.83	0.77	0.83	0.774	0.83	0.774	0.83	0.774
Digestible threonine (%)	0.74	0.71	0.74	0.709	0.74	0.709	0.74	0.709
Digestible tryptophan (%)	0.20	0.21	0.20	0.206	0.20	0.206	0.20	0.206
Sodium (%)	0.20	0.20	0.20	0.195	0.20	0.195	0.20	0.195

*** Folic Acid (min.) 45.00 mg/kg; Pantothenic acid (min.) 600.00 mg/kg; Beta-xylanase (min.) 800,000.00 U/kg; Copper (min.) 630.00 g/kg; Hill (min.) 32.00 g/kg; Iron (min.) 5,250.00 mg/kg; Phytase (min.) 50,000.00 FTU/kg; Iodine (min.) 126.00 mg/kg; Lysine (min.) 198.60 g/kg; Manganese (min.) 7,000.00 mg/kg; Methionine (min.) 239.60 g/kg; Niacin (min.) 2,400.00 mg/kg; Selenium (min.) 30.00 mg/kg; Threonine (min.) 61.10 g/kg; Vitamin A (min.) 600,000.00 IU/kg; Vitamin B1 (min.) 180.00 mg/kg; Vitamin B12 (min.) 1,080.00 mcg/kg; Vitamin B2 (min.) 360.00 mg/kg; Vitamin B6 (min.) 195.00 mg/kg; Vitamin D3 (min.) 150,000.00 IU/kg; Vitamin E (min.) 1,200.00 IU/kg; Vitamin K (min.) 150.00 mg/kg; Zinc (min.) 6,300.00 mg/kg; salinomycin 6,600.00 mg/kg; 3-nitro acid 4,000.00 mg/kg; tylosin 5,500.00 mg/kg.**

leftover feed were performed to calculate performance indices (feed consumption, weight gain, feed conversion and mortality). The data were tabulated by repetition, that is, each box with 20 birds was considered an experimental unit.

Blood calcium levels were measured at days 21 and 42. Blood was collected from two bird per pen using an insulin syringe. Blood was stored in microtubes without anticoagulant, and centrifuged at 5500 *g* for 10 min to obtain the serum that was frozen (–20 ºC) until analysis. Calcium levels were measured using a specific commercial kit (Analisa®) and read on semi-automatic equipment (Bioplus 2000®), following the manufacturer's recommendations.

At the end of the experiment, three birds from each repetition were also selected and weighed (individually), corresponding to the average weight of the repetition. Then, these birds were identified and sent for slaughter, after a 6-hour fast and 2-hour rest. In the refrigerator, all birds were weighed again, to obtain the slaughter weight, which served as a reference for calculating the meat (carcass) yield described below. The carcass of the birds was weighed, and abdominal fat was removed and weighed. Then, the cuts of the breast, legs, back and wings were made using a knife. Cut yields were calculated using the relationship between their respective weights and the weight of the carcass, without cooling in a tank with water and ice according to Mendes (2001).

Statistical analysis

The data obtained were subjected to the analysis of normal distribution and then to analysis of variance. In cases of significant differences, the means were subjected to polynomial regression and were compared using the Tukey test (5%). For the mortality variable, a non-parametric test was used because of lack of normal distribution, and the Kruskal–Wallis test (5%) was applied.

RESULTS AND DISCUSSION

IER presented a chemical composition based on the percentage of crude protein of 7.5% (Table IV), a value close to that found in corn grain.

Table IV. Values obtained for chemical composition and gross energy of the egg industrialization residue.

Variable	%
Dry matter	98.4
Crude protein	7.50
Calcium	31.0
Total phosphorus	0.16
Ethereal extract	1.85
Ash	86.7
Crude energy (Kcal/Kg)	635

Gross energy was 635 Kcal/kg, resulting from the burning of fats, proteins and carbohydrates present in IER. The percentage of calcium found in the residue was 31%, an amount similar to that found in calcitic limestone (37.8%). This suggests that inclusion of IER to replace calcitic limestone may be a viable alternative, because the source of calcium present in the egg shell is the same as that of calcitic limestone (calcium carbonate, $CaCO_3$).

The AME obtained for IER in broilers was 209 kcal/kg (Table V), which corresponds approximately to 1/3 of the determined gross energy. Based on the inclusion of IER in the diets, it was observed that the metabolizable energy provided by this ingredient was minimal, around 2.7 kcal/kg of the diet at its maximum inclusion level (100%).

The digestibility coefficient of dry matter and protein was high (83.95 and 86.20%, respectively), suggesting that this ingredient has a high efficiency of use by the birds, even with the high level of mineral matter. According to Shirley & Parsons (2001), the protein quality of mineral-rich ingredients such as meat and bone meal is affected by its high mineral concentration.

The calcium digestibility coefficient was 67%, a value considered good; however, it was lower than that the value reported by

Table V. Results obtained for apparent metabolizable energy (AEM), apparent digestibility coefficient of dry matter (CD DM), apparent digestibility coefficient of crude protein (CD CP), apparent digestibility coefficient of calcium (CDa Ca) and apparent digestibility coefficient of phosphorus (CDa P).

Variable	%
CDa DM	83.95
CDa CP	86.20
CDa Ca	67.00
CDa P	12.00
AME (Kcal/Kg)	209.95

Sá et al. (2004) for broilers that consumed calcitic limestone (84.67%). The phosphorus digestibility coefficient was low (12%), probably due to the low concentration of this mineral in IER. In general, IER proved to be an attractive alternative ingredient for the diet of broiler chickens, because of the fact that most of the digestibility coefficients were high.

There was no significant difference between treatments in terms of performance variables of the birds during all evaluated breeding phases (Table VI). These findings suggest that IER effectively provided the necessary calcium for the broilers; birds maintained their growth performance in a manner similar to those that consumed conventional ingredients. The findings also suggest a possible use for IER, because many companies would otherwise partially or totally discard this material. A recent study by our research group showed that the IER supplementation in laying hen feed maintained the production and quality of eggs in the short term (56 days of consumption); however, after this period, the hens had behavioral changes characterized by egg breaking and consumption, dramatically reducing performance (Barreta et al. 2021).

The levels of substitution of calcitic limestone by IER in the feed of the chickens did not influence the amount of calcium in

Table VI. Averages obtained for feed consumption (FC, kg), Body weight (BW, kg), weight gain (WG, kg) and Feed conversion ratio (FCR) of birds fed with diets containing different levels of IER inclusion in the respective periods of creation.

Treatments	FC	BW	WG	FCR
	1–21 days			
0	1.09	0.88	0.84	1.29
35	1.08	0.86	0.82	1.31
70	1.06	0.85	0.81	1.30
100	1.10	0.88	0.83	1.32
P	0.75	0.69	0.68	0.56
CV (%)	6.42	5.44	5.72	7.92
	1–35 days			
0	3.11	2.31	2.27	1.37
35	3.14	2.36	2.31	1.36
70	3.00	2.28	2.24	1.34
100	3.09	2.33	2.29	1.35
P	0.09	0.35	0.35	0.21
CV (%)	5.39	2.33	2.36	7.25
	1–42 days			
0	4.54	2.99	2.95	1.54
35	4.88	3.25	3.21	1.52
70	4.60	3.05	3.01	1.53
100	4.73	3.10	3.06	1.54
P	0.12	0.23	0.23	0.95
CV (%)	4.05	4.39	5.59	4,99

CV = coefficient of variation.

the blood (Figure 1); a similar result to that was described by Barreta et al. (2021) when they used similar levels of IER substitution in hens. We found that total plasma calcium concentrations were near 6 and 7 mg/dL at 21 and 42 days of age, respectively (Figure 1). These values are close to those reported by Diaz et al. (1997), who reported serum levels of 10 mg/dL. According to Veum (2010) plasma Ca and P levels are controlled in a narrow physiological range by means of feedback mechanisms that involve parathyroid hormone, active vitamin D3, calcitonin and their respective receptors located in the small intestine, bone, and kidneys. These findings suggest that both sources of calcium used in this study are efficient in making the mineral available to chickens.

There were no significant differences regarding the percentages of carcass yield, breast yield, feather yield or back yield (Table VII). With respect to the yield of wings and abdominal fat, there was a significant difference, where a linear reduction in the abdominal fat of the birds was noted as the IER was included in the diets (equation $Y = 1.3412 - 0.00798X$; $R^2 = 0.73$). Quadratic behavior was observed for wing performance (equation $Y = 9.92 + 0.02148X - 0.00017167X^2$; $R^2 = 0.41$).

This linear behavior was due to the reduction in the levels of soybean oil as the levels of IER increased, as according to Cancherini et al. (2005); when vegetable oil was added to the diet, abdominal fat accumulated. Yields of abdominal fat and wings are the lowest when compared to other cuts. This suggests that the variation in the percentage of abdominal fat may have caused the same in wing performance, only in reverse. Nevertheless, the mechanism involved in the reduction of abdominal fat should be explored in future studies, and the analysis of lipid profile in broilers fed with IER must be evaluated.

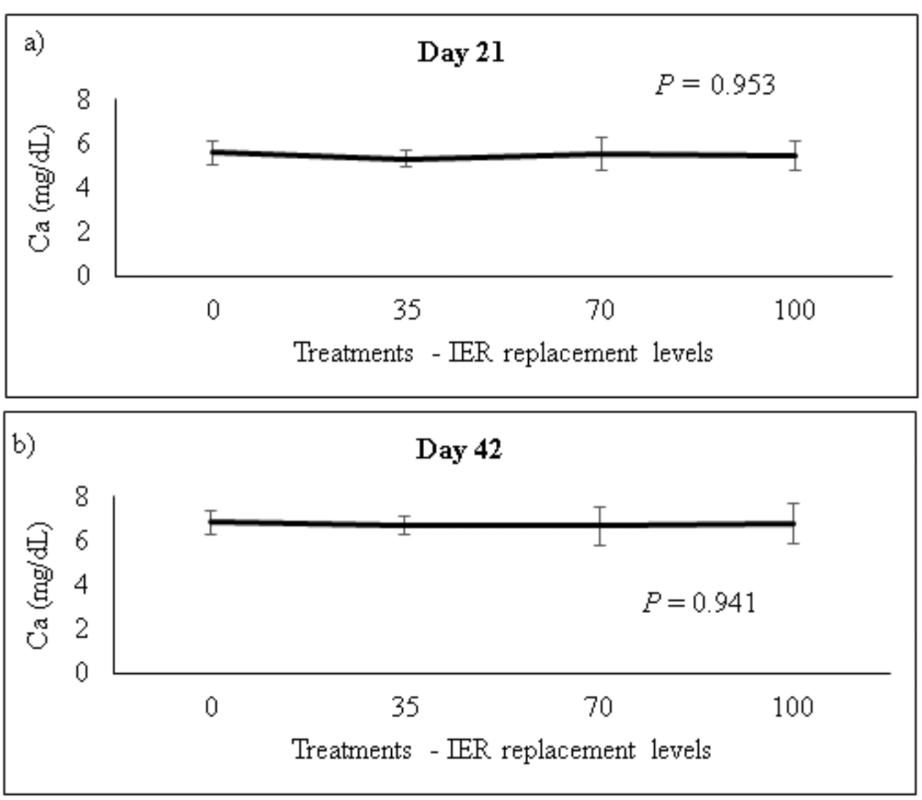

Figure 1. Calcium (Ca) levels in broilers serum at 21 (a) and 42 (b) days of age. There was no difference between treatments (P>0.05).

Table VII. Means obtained for percentage of carcass yield (CY), breast (Br), legs (L), wings (W), abdominal fat (AF) and back (Ba) of birds fed diets containing different levels of inclusion of IER in creation periods.

Treatments	CY	Br	L	W	AF	Ba
0	75.80	39.49	30.22	9.91 B	1.35 A	19.16
35	75.05	38.94	30.73	10.47 AB	1.06 B	19.04
70	74.30	39.51	29.74	10.55 A	1.04 B	19.34
100	74.63	40.05	29.37	10.36 AB	0.93 B	19.38
P	0.568	0.598	0.324	0.035	< 0.001	0.971
CV (%)	2.05	2.80	3.40	2.63	8.19	5.87

A, B Different letters in the same column indicate significant difference by the Tukey test (P <0.05). CV = coefficient of variation.

CONCLUSION

Industrial egg residue contains 7.5% of crude protein, 31% of calcium, and 209 kcal/kg of apparent metabolizable energy that corresponds to 1/3 of the gross energy. There were high digestibility coefficients for dry matter, crude protein and calcium. Serum calcium levels were the same in all treatments, which shows that IER is a great source of calcium for broilers. The growth performance of broiler chickens remained high with the replacement of up to 100% of the calcitic limestone by IER, allowing us to conclude this new ingredient is a viable alternative for broiler feed. The consumption of IER by broilers maintained high carcass yields, as well as yields of the main cuts. The inclusion of IER reduced visceral fat in birds, which is positive for animal health as well as for meat yield.

Acknowledgments

We thank Fundação de Amparo á Pesquisa e Inovação do Estado de Santa Catarina (FAPESC), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for their financial support.

REFERENCES

ARAUJO JA, SILVA JHV, AMÂNCIO ALL, LIMA CB & OLIVIERA ERA. 2008. Fontes de minerais para poedeiras. Acta Vet Bras 2: 53-60.

BARRETA M, BOIAGO MM, ZAMPAR A & DA SILVA AS. 2021. Inclusion of industrial egg residue in the feed of laying hens to replace calcitic limestone: digestibility, productive performance and egg quality. An Acad Bras Cienc 93: e20190769.

CANCHERINI LC, JUNQUEIRA OM & OLIVEIRA MC. 2005. Utilização de subprodutos de origem animal em dietas formuladas com base em proteína bruta e proteína ideal para frangos de corte de 22 a 42 dias de idade. R Bras Zoot 34: 535-540.

DIAZ R, HURWITZ S, CHATTOPADHYAY N, PINES M, YANGY, KIFOR O, EINAT MS, BUTTERS R, HEBERT SC & BROWN EM. 1997. Cloning, expression, and tissue localization of the calcium-sensing receptor in chicken (Gallus domesticus). Am J Physiol 273: R1008-R1016.

GARCIA JR AAP. 2010. Equações de predição dos valores energéticos de farinha de origem animal para aves, utilizando o princípio da meta-analise. Dissertação Mestrado apresentada a Universidade Federal de Lavras. Lavras: UFLA, 57 p. (Unpublished).

MELO TV, MENDONÇA PP, MOURA AMA, LOMNARDI CT, FERRIERA RA & NERY VLH. 2006. Solubilidad in vitro de algunas fuentes de calcio utilizadas em alimentacion animal. Arch Zoot 55: 29-37.

MELO TV & MOURA AMA. 2009. Utilização da farinha de algas calcáreas na alimentação animal. Arch Zoot 58: 99-107.

MENDES AA. 2001. Rendimento e qualidade da carcaça de frangos de corte. In: Conferência Apinco de Ciencia e Tecnologia Avicolas, Campinas. Anais...Campinas: APINCO, p. 79-99.

MURAKAMI FS, RODRIGUES PO & CAMPOS CMT. 2007. Physicochemical study of $CaCO_3$ from egg shells. Ciênc Tecnol de Aliment 27: 658-662.

OLIVIERA GE, FIGUIEREDO TC & SOUZA MR. 2009. Bioactive amines and quality of egg from dekalb hen under different storage conditions. Poult Sci 88: 2428-2434.

ROSTAGNO HS. 2017. Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais. 4. ed. Viçosa, MG: UFV, p. 237-251.

SAKOMURA NK & ROSTAGNO HS. 2007. Métodos de pesquisa em nutrição de monogástricos. Jaboticabal: Funep, 283 p.

SÁ LM, GOMES PC, ALBINO LFT, ROSTAGNO HS & D'AGOSTINI P. 2004. Calcium requirement and bioavailability of some feedstuffs for broiler chicks from 1 to 21 days old. Rev Bras Zoot 33: 157-168.

SHIRLEY RB & PARSONS CM. 2001. Effect of ash content on proteinquality of meat and bone meal. Poult Sci 80: 626-632.

SILVA DJ & QUEIROZ AC. 2012. Analise de alimentos: métodos químicos e biológicos 3. ed. Viçosa, MG: UFV, 235 p.

VEUM TL. 2010. Phosphorus and calcium nutrition and metabolism. In: Phosphorus and Calcium Utilization and Requirements in Farm Animals. CAB International, Oxfordshire, Uk, p. 94-111.

How to cite

NOVACK C ET AL. 2023. Industrial egg residue as a calcium source in broiler feed: digestibility and growth performance. An Acad Bras Cienc 95: e20201688. DOI 10.1590/0001-3765202320201688.

Manuscript received on October 23, 2020;
accepted for publication on December 20, 2020

CLAUDIO NOVACK[1]
https://orcid.org/0009-0007-4715-7952

MARCEL M. BOIAGO[1]
https://orcid.org/0000-0002-0950-4577

ALINE ZAMPAR[1]
https://orcid.org/0000-0002-2269-7932

MAURICIO BARRETA[1]
https://orcid.org/0000-0001-6261-2182

ROSILENE OLIVEIRA[1]
https://orcid.org/0000-0001-6261-2182

EDUARDO ROSCAMP[1]
https://orcid.org/0000-0002-4770-7578

JÉSSICA D. DILKIN[1]
https://orcid.org/0000-0002-2830-3930

TIAGO G. PETROLLI[1]
https://orcid.org/0000-0002-6175-5939

DENISE N. ARAUJO[1]
https://orcid.org/0000-0001-9606-5447

FERNANDO C. TAVERNARI[2]
https://orcid.org/0000-0002-3161-019X

MARCOS T. LOPES[3]
https://orcid.org/0009-0003-8782-5725

ALEKSANDRO S. DA SILVA[1]
https://orcid.org/0000-0001-5459-3823

[1]Universidade do Estado de Santa Catarina, Departmento de Zootecnia, Rua Beloni Trombeta Zanini, 680E,89815-630 Chapecó, SC, Brazil

[2]Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA Suínos e Aves, BR 153, Km 110, 89700-000 Concórdia, SC, Brazil

[3]Cooperativa Central Aurora Alimentos, Rua João Martins, 219 D, São Cristóvão, 89803-901 Chapecó, SC, Brazil

Correspondence to: **Marcel M. Boiago, Aleksandro S. da Silva**
E-mail: mmboiago@gmail.com
E-mail: dasilva.aleksandro@gmail.com

Author contributions

CN, MMB, ASS and MB elaborated the project, performed the experiments and revised the manuscript. AZ performed the statistical analyzes and revised the manuscript. TGP, FCT, MTL and DNA revised the manuscript. MMB, MB, RO, ER and JDD were responsible for daily handling of the animals and laboratory analysis.