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Bacillus coagulans as an alternative to antibiotics in the performance and control of *Salmonella* Enteritidis in broilers

Bacillus coagulans como alternativa aos antibióticos sobre o desempenho e controle da Salmonella Enteritidis em frangos de corte

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ABSTRACT

The use of antimicrobial growth promoters in broiler feed has been beneficial for improving performance and preventing diseases. However, the indiscriminate use of these products in the feed can result in the development of resistant bacteria, the accumulation of residues in the products, and an imbalance in the microflora of birds. Therefore, it is necessary to evaluate alternatives, such as beneficial microorganisms that improve microbial growth without affecting animal health and product quality. This research aimed to evaluate the supplementation with the probiotic *Bacillus coagulans* on the performance, carcass characteristics, and health of broilers from seven to 42 days. In total, 720 broilers were used, distributed in a randomized block design with six treatments and eight replicates. The evaluated treatments were as follows: Control ration (RC); PROB1 (Probiotic 400 g/t); PROB2 (Probiotic 400 g/t until 21 days and 200 g/t from 22 to 42 days); RC + antibiotic; RC + *Salmonella* inoculation; PROB1 + *Salmonella* inoculation. The treatments did neither influence feed intake, carcass yield, and cuts nor the incidence of injuries to the chest, hock, and footpad. Weight gain and feed conversion were better in birds that received antibiotic or probiotic diets. There was an incidence of *Salmonella* in the e challenges excreta at 42 days only in the treatment with challenge without adding probiotics. We conclude that the probiotic *Bacillus coagulans* can be used as an alternative to antibiotics in the diet of broilers as it facilitates similar performance and is efficient in the control of *Salmonella* Enteritidis.

KEYWORDS: additives; poultry; salmonellosis; intestinal contamination.

RESUMO

A utilização de promotores de crescimento antimicrobianos na alimentação de frangos de corte tem sido benéfica para melhoria do desempenho e para prevenção de doenças. Porém, o uso indiscriminado destes produtos nas rações pode resultar em desenvolvimento de bactérias resistentes, acúmulo de resíduos nos produtos e desequilíbrio da microflora das aves. Portanto, torna-se necessário avaliar alternativas como microrganismos benéficos que melhorem o crescimento microbiano, sem afetar a saúde do animal e a qualidade dos seus produtos. Objetivou-se com esta pesquisa avaliar a suplementação do probiótico *Bacillus coagulans* sobre o desempenho, características de carcaça e saúde de frangos de corte de 7 a 42 dias. Utilizou-se 720 frangos de corte distribuídos em delineamento em blocos casualizados, com seis tratamentos e oito repetições. Os tratamentos avaliados foram: Controle; PROB1 (Probiótico 400 g/t); PROB2 (Probiótico 400 g/ton até os 21 dias e 200 g/t dos 22 aos 42 dias); Controle + antibiótico; Controle + inoculação de *Salmonella*; PROB1 + inoculação de *Salmonella*. Os tratamentos não influenciaram o consumo de ração, rendimento de carcaça e cortes e a incidência de lesões no peito, jarrete e coxim plantar. O ganho de peso e a conversão alimentar foram melhores nas aves que receberam rações com antibiótico ou probiótico. Houve incidência de *Salmonella* nas excretas aos 42 dias somente no tratamento com desafio sem adição de probiótico. Conclui-se que o probiótico *Bacillus coagulans* pode ser usado como alternativa ao antibiótico na ração de frangos de corte, pois proporciona desempenho semelhante e é eficiente no controle da *Salmonella* Enteritidis.

PALAVRAS-CHAVE: aditivos; aves; salmonelose; contaminação intestinal.

INTRODUCTION

Salmonellosis is among the four main causes of diarrheal diseases in the world. Each year, an estimated 550 million people are affected by this disease. The serotypes *Salmonella* Enteritidis and *Salmonella* Typhimurium are the ones most related to salmonellosis outbreaks because of the high number of isolations worldwide (WHO 2018).

Animals are natural reservoirs of *Salmonella*, and it is common to find it in the gastrointestinal tract of numerous species; many *Salmonella* species are associated with birds and their products (SOARES et al. 2020, STELLA et al. 2021). When broiler chickens are contaminated while still in the breeding house, they can become carriers, and the spread of *Salmonella* to other carcasses can occur due to fecal contamination during slaughtering. Thus, the industrial processing of chickens to obtain carcasses and cuts for consumption are risk factors for contamination, especially during evisceration, cooling, packaging, and transportation (ZIBA et al. 2020).

In this context, in the broiler production chain, part of the health problems has been reduced with the use of additives, especially antibiotics. But, on the other hand, there is a growing concern about the use of subtherapeutic concentrations of these products, related to the emergence of resistant microorganisms in animals, with the possibility of transmitting this resistance to humans (DIARRA & MALOUIN 2014).

Faced with such a problem, some researchers began evaluating possible antibiotic alternatives. One of the alternatives would be the use of probiotics, which can be defined as microbial food supplements that beneficially affect the host, improving its intestinal microbial balance (KHAN & NAZ 2013). According to RAMOS et al. (2014), because they are natural, non-toxic products that do not induce bacterial resistance, probiotics can be used in the feed, seeking to favor a certain bacterial population in ideal conditions in the digestive tract, without negatively impacting health, nutrient absorption, and animal performance.

A wide variety of probiotics can be used in broiler chickens, and research has shown that they can be technically viable alternatives to antimicrobial growth promoters (KURITZA et al. 2014).

Given the above, the objective of this research was to evaluate the supplementation with probiotics (*Bacillus coagulans*) in broiler diets and the impacts on performance, carcass and viscera characteristics, the incidence of dermatological lesions, and incidence of *Salmonella* Enteritidis in excreta.

MATERIALS AND METHODS

The Ethics Committee approved the Experimentation and Animal Welfare experiment of the State University of Montes Claros (CEEBEA), Montes Claros, MG, Brazil, under protocol number 202/2019.

The experiment was conducted at the Poultry Production Laboratory of the Federal Institute of Science and Technology Education of Northern Minas Gerais, campus Januária, MG. In total, 720 male and female Cobb broilers with an initial age of seven days and an average weight of 135.0 ± 29 g were used. The birds were housed in a conventional broiler house which as subdivided into boxes of 1.0 x 1.5 m; the floors were covered with wood shavings and a reused bed (once) in a 1:1 ratio. Each box was equipped with a tubular feeder and a pendant drinker, with water and feed provided *ad libitum*. Temperature and humidity inside the shed were recorded every five minutes using a datalogger, obtaining averages of 26.57 ± 2.99 °C and 75.37 ± 12.38%, respectively.

The birds were distributed in a randomized block design, with six treatments with eight repetitions of 15 birds each. The boxes (experimental units) were organized in four longitudinal lines in the shed, each with two repetitions of each treatment. Six treatments were evaluated, namely RC = Control ration; PROB1- control ration with the addition of 400g/t of probiotics throughout the experimental period; PROB2 = control ration with the addition of 400g/t of probiotics until 21 days and 200g/t from 22 to 42 days of age; ATB = control ration with 180g/t of inclusion of zinc bacitracin; RC + challenge = control ration + addition of 1 ml of a solution with *Salmonella* in the water at 21 days; PROB1 + challenge = control ration supplemented with 400 g/t of probiotic + addition of 1 ml of a solution with *Salmonella* in the water at 21 days.

The probiotic used was composed of *Bacillus coagulans* (DSM 32016) at a dosage of 0.5-1.0 x 10^9 CFU. In order to cause a sanitary challenge to the birds, a protocol was created that consisted of inoculating, via drinking water at 21 days of age, 1 mL of a solution containing *Salmonella* Enteritidis colonies (dosage of 2.5 x 10^6 CFU) diluted in two liters of water in the RC + challenge and PROB 400 + challenge. The *Salmonella* Enteritidis solution was obtained from the CDMA Laboratory (Centro de Diagnóstico e Monitoramento e Animal, Belo Horizonte, MG, Brasil). The diets were prepared for three phases: initial, seven to 21 days; growth, 22 to 35 days; final, 36 to 42 days (Table 1), formulated based on corn and soybean meal as recommended by ROSTAGNO et al. (2017).

Table 1. Composition and nutritional levels of standard feed at different stages of growth.

	Phase		
Ingredient (%)	7-21 d	22-35 d	36-42 d
Corn	65.76	66.97	67.31
Soybean meal	30.00	28.24	27.00
Soy oil	0.00	0.95	1.82
Sodium bicarbonate	0.10	0.10	0.10
Dicalcium phosphate	1.70	1.50	1.50
Limestone	0.86	0.82	0.82
Common salt	0.44	0.44	0.44
Vitamin/mineral supplement	1.50	1.50	1.50
DL- methionine 99%	0.30	0.23	0.11
L- lysine HCl 99%	0.29	0.25	0.37
L- threonine 98%	0.10	0.05	0.08
	Calculated Nutritional Level		
Metabolizable energy, kcal/kg	3.036	3.100	3.151
Crude protein, %	19.925	19.101	18.613
Digestible lysine, %	1.142	1.067	1.129
Methionine, %	0.568	0.491	0.367
Methionine + Digestible cystine, %	0.847	0.762	0.631
Threonine digestible, %	0.767	0.695	0.705
Tryptophan, %	0.213	0.204	0.197
Calcium, %	0.838	0.770	0.767
Available phosphorus, %	0.421	0.382	0.380
Sodium, %	0.207	0.207	0.206

[1]Guarantee levels (kg of product): vit. A - 10,000,000 IU; vit. D3 - 2,000,000 IU; vit. E - 30,000 IU; vit. B1 = 2.0 g; vit. B2 - 6.0 g; vit. B6 - 4.0 g; vit. B12 - 0.015 g; pantothenic BC - 12.0 g; biotin - 0.1 g; vit. K3 = 3.0 g; folic acid - 1.0 g; nicotinic acid 50.0 g; Se - 250.0 mg; Fe - 80 g; g Cu-10; Co 2 g; Mn - 80 g; Zn - 50 g; I - 1 g.

From seven to 42 days of age, we evaluated the following performance variables: weight gain, feed intake, and feed conversion. At 21, 36, and 42 days of age, three birds from each experimental unit were inspected for evaluation of dermatological lesions in the sole and hock and classified according to the WELFARE QUALITY® (2009). At 36 and 42 days, analysis of chest lesions was performed following the methodology of JONG et al. (2014).

At ten, 22, and 42 days, swabs were collected from the cloaca of three birds per experimental unit to verify the presence of *Salmonella* Enteritidis. In addition, the bacterium *Salmonella* Enteritidis (ATCC 13076) was used as a reference strain in m-PCR assays. All procedures followed the methodology used by PAIÃO et al. (2013).

To evaluate the carcass yield and commercial cuts at 42 days of age, after an 8-hour fasting period, three birds from each experimental unit were selected, weighed, and labelled with numbered plastic tags. After slaughter, bleeding, scalding, feather removal, and evisceration, hot and cold carcasses without heads were weighed. Subsequently, they were subjected to cut (chest, back, thighs, drumsticks, wings, and feet) and abdominal fat collection. In addition, the proventricle, pancreas, gizzard, heart, liver, spleen, and lung were weighed, and the small intestine (duodenum, jejunum, and ileum) and large intestine (cecum, colon, and rectum) were weighed and measured (mm).

The data were submitted to covariance analysis using the PROC GLM procedure to verify the effects of experimental treatments and blocks. The initial weight of the chicks was a covariate in the model. The least squares procedure was used to compare the means when the F value was significant ($p<0.05$). A comparison between means was performed using the SNK test ($p<0.05$). For the sanitary parameter (presence or not of *Salmonella* Enteritidis in the excreta), the Kruskal-Wallis test was performed to verify the homogeneity of the variance; when not confirmed, this homogeneity followed the Friedman test ($p\leq0.05$) to compare groups.

RESULTS AND DISCUSSION

Weight gain was greater in chickens that received diets with probiotics (400 g/t until 21 days and 200 g/t from 22 to 42 days), with similar results compared to those that received antibiotics. Feed conversion was better in birds that received diets containing only probiotics and antibiotics. The different treatments did not influence the feed intake of the birds (Table 2).

Table 2. Average weight gain (WG), feed intake (FI), and feed conversion (FC) of broilers fed probiotics or antibiotic from seven to 42 days of age.

Variable	Treatment							
	CR	PROB1	PROB2	ATB	CR + challenge	PROB1 + challenge	CV	*P*
WG (g)	2.844b	3.027ab	3.061a	3.072a	2.840b	2.926ab	4.82	0.0031
FI (g)	4.858	4.823	4.762	4.841	4.828	4.807	3.95	0.9395
FC	1.719a	1.595b	1.556b	1.577b	1.702a	1.646ab	5.15	0.0011

Means followed by different letters differ by the SNK test ($p<0.05$); CR = Control ration, PROB1 = CR with the addition of 400g/t of probiotics throughout the experimental period, PROB2 = CR with the addition of 400 g/t of probiotics until 21 days and 200 g/t of 22 to 42 days of age, ATB= CR with 180g/t of inclusion of zinc bacitracin; challenge = 1 ml of a solution containing strains of *Salmonella* Enteritidis at 21 days of age.

WANG & GU (2010) e SUMIATI & NAHROWI (2020) also found better weight gain and feed conversion in broilers that received feed supplemented with *Bacillus coagulans* when compared to those that did not receive this probiotic. The authors attributed these results to the greater activity of the protease and amylase enzymes observed in the duodenum of the chickens that received probiotics, leading to improved nutrient use and, consequently, better performance.

Assessing the use of *Bacillus coagulans* in broiler diets, HUNG et al. (2012) also observed better feed conversion in chickens that received the probiotic or antibiotic (zinc bacitracin) in the feed compared to those that did not receive additives. In addition, the authors found a larger population of lactobacilli in the duodenum and a greater villi height in the jejunum of chickens that received the probiotic, which may have contributed to better intestinal health and greater nutrient absorption, facilitating improved performance.

Similar to our results, JAYARAMAN et al. (2013) found better feed conversion of chickens infected with the bacterium *Clostridium perfringes* and that received a diet supplemented with probiotics (*Bacillus subtilis*). In addition, the authors observed a lower number of bacteria and less lesions in the small intestine of the chickens that received the probiotic, resulting in better organ integrity, which probably led to a better absorption of nutrients, positively influencing the performance results.

SILVA et al. (2018) also found no differences in feed intake of broilers when comparing the use of antibiotics (avilamycin) and probiotics composed of bacteria of the genera *Lactobacillus*, *Bifidobacterium*, *Streptococcus*, and *Enterococcus*. However, contrary to the present research, the authors did not observe differences between the control diet and the others in relation to feed conversion.

In contrast to our findings, ZHEN et al. (2018), evaluating *Bacillus coagulans* for broiler chickens, observed an improvement in performance only in the period of 15 to 21 days among birds infected with *Salmonella* Enteritidis and those infected that did not receive the probiotic. However, the authors observed positive effects of the probiotic on intestinal health and morphology through the inhibition of bacterial colonization by *Salmonella* and coliforms in the cecum and an increase in the villus: crypt ratio in the birds' duodenum.

There were no differences between treatments for carcass yield and cuts, viscera weights and abdominal fat, and intestinal morphometry (Table 3).

In research with broilers, which received diets with antibiotics (avilamycin), probiotics (*Lactobacillus acidophilus, Streptococcus faecium*, and *Bifidumbacterium bifidum*), prebiotics (mananoligosaccharide), and symbiotics, RAMOS et al. (2014) also observed that the tested additives acted in a similar way to the antibiotics on the carcass and cuts yield, constituting an alternative in the substitution of growth-promoting antibiotics.

Evaluating *Bacillus coagulans* for broilers, BAMI et al. (2019) observed no effects of probiotics on carcass and cut characteristics. However, the birds that received probiotic feed had lower liver weights and less abdominal fat. The authors attribute the lighter weight of the liver to a possible antioxidant action of the probiotic, a result also found by BAI et al. (2017), who verified a higher production of antioxidant enzymes by broilers fed with the probiotic *Bacillus subtilis*. Lower deposition of abdominal fat was observed by WANG et al. (2017) e TANG et al. (2021) in broilers that received the probiotic *Lactobacillus johnsonii*. The authors verified the action of the probiotic on lipid metabolism by inhibiting the expression of the enzyme lipase lipoprotein in adipose tissue at 21 days of age, which may have contributed to the lower deposition of abdominal fat subsequently observed at 42 days of age.

There were no significant effects between treatments for the incidence of *Salmonella* Enteritidis at ten and 22 days of age (Table 4).

Table 3. Average live weight, carcass yield and cuts, viscera weights and abdominal fat, and intestinal morphometry of broilers fed different levels of probiotics or antibiotics from 7 to 42 days of age.

Variable	Treatment							
	CR	PROB1	PROB2	ATB	CR + challenge	PROB 1 + challenge	CV	*P*
Live weight (kg)	2.79	2.77	2.768	2.91	2.85	2.82	8.96	0.7064
Carcass + offal (kg)	2.49	2.50	2.520	2.60	2.54	2.54	9.77	0.8992
Empty carcass (kg)	2.24	2.21	2.258	2.38	2.31	2.28	11.45	0.2952
Carcass yield (%)	80.32	79.77	81.58	82.01	81.24	80.91	-	-
Legs (g)	572.0	578.0	557.0	601.0	563.0	616.0	11.51	0.4604
Feet (g)	103.0	100.0	100.0	103.0	97.0	105.0	17.32	0.9541
Breast (g)	794.0	834.0	767.0	703.0	771.0	823.0	18.20	0.5101
Breast (%)	28.39	30.03	27.71	24.15	27.07	29.16	-	-
Breast fillet (g)	674.0	682.0	643.0	673.0	684.0	644.0	12.69	0.8584
Breast fillet (%)	24.12	24.55	23.22	23.10	23.99	22.82	-	-
Neck (g)	59.0	59.0	57.5	60.0	56.3	57.5	18.12	0.9837
Wings (g)	215.0	212.0	216.0	222.0	216.0	236.0	11.50	0.4660
Heart (g)	12.75	12.18	12.90	11.51	12.17	13.07	17.02	0.6935
Liver (g)	56.38	47.00	52.28	47.47	51.90	51.82	13.03	0.0952
Spleen (g)	3.03	2.65	3.28	2.97	2.93	3.08	29.32	0.8084
Lungs (g)	10.01	12.61	11.07	11.18	10.01	10.65	30.03	0.6308
Proventricle (g)	9.53	9.23	10.33	9.513	9.88	10.05	17.01	0.7934
Gizzard (g)	45.23	41.86	43.28	43.26	43.65	41.63	11.80	0.7530
Duodenum (g)	23.150	22.75	26.600	23.31	24.51	25.40	25.31	0.7922
Abdominal fat (g)	26.31	25.43	26.62	23.96	22.85	23.16	36.98	0.9364
Duodenum length (mm)	36.20	35.9	36.00	35.6	34.70	36.30	10.86	0.7373
Jejunum (g)	35.76	33.92	35.16	31.08	34.06	34.37	20.43	0.8240
Jejunum length (mm)	82.30	79.50	80.40	80.10	80.30	78.80	10.54	0.8048
Ileum (g)	28.70	28.82	30.27	26.91	29.71	29.48	16.33	0.7829
Ileum length (mm)	89.20	86.30	87.00	89.30	88.40	89.30	10.53	0.8129
Right cecum (g)	7.313	7.73	6.913	7.975	7.52	8.47	21.54	0.5140
Right cecum length (mm)	20.90	20.30	20.80	20.20	20.60	20.60	10.86	0.8337
Left cecum (g)	7.013	7.938	6.98	8.175	7.63	8.65	27.15	0.5665
Left cecum length (mm)	20.80	20.60	20.60	20.50	21.10	20.80	10.40	0.9376
Colon (g)	2.800	3.05	2.73	3.213	2.76	3.25	20.89	0.3642
Colon length (mm)	8.17	8.42	7.83	8.71	8.21	8.04	16.50	0.3123
Rectum (g)	2.23	1.88	1.63	2.088	1.77	1.67	32.82	0.7823
Rectum length (mm)	3.09	3.25	3.13	3.46	3.13	3.46	24.27	0.4060

CR = Control ration, PROB1 = CR with the addition of 400 g/t of probiotics throughout the experimental period, PROB2 = CR with the addition of 400 g/t of probiotics until 21 days and 200 g/t of 22 to 42 days of age, ATB = CR with 180 g/t of inclusion of zinc bacitracin; challenge = 1 ml of a solution containing strains of *Salmonella* Enteritidis at 21 days of age.

Table 4. Incidence of *Salmonella* Enteritidis in the excreta (SE EXC) of broilers at ten, 22, and 42 days of age of broilers fed different levels of probiotics or antibiotics from seven to 42 days of age.

	Treatment							
Variable	CR	PROB1	PROB2	ATB	CR + challenge	PROB 1 + challenge	CV	*P*
SE EXC 10 d	(-)	(-)	(-)	(-)	(-)	(-)	0.00	-
SE EXC 22 d	(-)	(-)	(-)	(-)	(-)	(-)	0.00	-
SE EXC 42 d	(-)	(-)	(-)	(-)	(+)	(-)	193.8	<0001

(+) = Positive for the presence of *Salmonella* Enteritidis; (-) = negative for the presence of *Salmonella* Enteritidis; CR = Control ration, PROB1 = CR with the addition of 400 g/t of probiotics throughout the experimental period, PROB2 = CR with the addition of 400 g/t of probiotics up to 21 days and 200 g/t from 22 to 42 days of age, ATB = CR with 180 g/t of zinc bacitracin inclusion; challenge = 1 ml of a solution containing strains of *Salmonella* Enteritidis at 21 days of age.

In these first analyses, the presence of *Salmonella* was not verified. This is an expected result at 10 days because the challenge with inoculation of the bacteria has not yet occurred. However, *Salmonella* was detected only at 42 days in the treatment with challenge and without adding any additives (probiotics or antibiotics). In the treatment (PROB 400 g/t + challenge), the chickens that were submitted to the challenge but those that received the probiotics in the feed (400 g/t) did not present any incidence of contamination by *Salmonella*, demonstrating the beneficial effect of probiotics.

The inhibitory effect of probiotics on the population of pathogenic enterobacteria through the competitive exclusion mechanism may be a possible explanation for the absence of *Salmonella* Enteritidis observed in the present study. Research in which *Bacillus coagulans* was evaluated in diets for broilers observed an increase in the population of *Lactobacillus* spp. and inhibition of *Escherichia coli* replication in the cecum (XU et al. 2017) and a higher incidence of *Lactobacillus* and *Bifidobacterium*, in addition to a lower incidence of *Salmonella* Enteritidis in the cecum (ZHEN et al. 2018) of birds that received the probiotic in the diet. These results demonstrate the effectiveness of this probiotic in promoting the intestinal health of birds as it stimulates the colonization of bacteria producing organic acids, which leads to a reduction in the pH of the intestinal environment, with consequent inhibition of the population of pathogenic bacteria (HUNG et al. 2012).

There were no differences between treatments for the lesions evaluated (Table 5).

Table 5. Average scores of dermatological lesions were observed in the footpad (DL FP), hock (DL HO), and breast (DL BR) of broilers fed different levels of probiotics or antibiotics from seven to 42 days of age.

	Treatment							
Variable	CR	PROB1	PROB2	ATB	CR + challenge	PROB 1 + challenge	CV	*P*
DL FP 21 d	0.79	0.88	0.88	0.58	0.75	0.95	54.39	0.0642
DL FP 36 d	1.83	1.50	1.25	1.54	1.71	1.38	50.34	0.1116
DL FP 42 d	1.88	2.04	2.25	1.83	2.29	1.71	48.77	0.2277
DL HO 21 d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
DL HO 36 d	0.71	0.50	0.88	0.58	1.00	0.50	99.14	0.1236
DL HO 42 d	0.79	0.92	0.71	0.92	0.92	0.75	111.39	0.9385
DL BR 36 d	0.83	1.04	1.17	0.71	1.13	0.96	95.17	0.5035
DL BR 42 d	0.88	0.96	0.67	0.96	1.13	1.00	87.02	0.5128

CR = Control ration, PROB1 = CR with the addition of 400 g/t of probiotics during the whole experimental period, PROB2 = CR with the addition of 400 g/t of probiotics until 21 days and 200 g/t from 22 to 42 days of age, ATB = CR with 180 g/t of inclusion of zinc bacitracin; challenge = 1 ml of a solution containing strains of *Salmonella* Enteritidis at 21 days of age.

These results agree with those obtained by TRALDI et al. (2007), who evaluated the use of probiotics (*Bacillus subtilis* and *Bacillus coagulans*) in broiler diets raised on reused litter. The authors observed that the use of probiotics did not significantly affect the scores of lesions in the hock and footpad. DERSJANT-LI et al. (2015) compared the use of a diet for broilers without additives with a diet containing probiotics (three strains of *Bacillus amyloliquefaciens*) combined with enzymes (xylanase, amylase, and protease). They observed a better litter quality (less humidity) and a lower incidence of lesions in the footpads of the birds that received the feed with the additives. Associated with lower humidity, a lower incidence of pathogenic bacteria (*Clostridium perfringes* and *Clostridium septicum*) was found in the ileum and cecum of the chickens that received the combination of additives, which contributed to a lower incidence of injuries since these bacteria are associated with plantar cushion dermatitis in these animals (LI et al. 2010). FLORES et al. (2016) also found a lower incidence of footpad injuries in chickens that received diets with probiotics (*Bacillus* spp.) combined with enzymes (xylanase, amylase, and protease) when compared to those that were fed diets without additives.

Another factor that can cause skin lesions in broilers is the concentration of ammonia in the excreta and in the litter. Some studies have already shown a reduction in ammonia in excreta when using probiotics in the diet of broiler chickens (AHMED et al. 2014 – *Bacillus amyloliquefaciens*) and laying hens (ZHANG & KIM 2013, PARK et al. 2016 - *Enterococcus faecium*). According to LIANG et al. (2014), the high humidity of the litter associated with the high temperature and high pH provides ideal conditions for a greater conversion of uric acid and urea into ammoniacal nitrogen, increasing the presence of lesions on the footpad and ammonia volatilization, which can generate respiratory problems in birds (NASEEM & KING 2018), leading to lower performance and economic losses.

The present research demonstrated that the probiotic *Bacillus coagulans* can be used as an alternative to the antibiotic in the control of *Salmonella* Enteritidis, resulting in similar performance, thus, complementary research is suggested with the strain used (DSM 32016) comparing it with different antibiotics. Furthermore, further studies on the influence of this strain on the bacterial population and on the immune system of broilers are also suggested.

CONCLUSION

The probiotic *Bacillus coagulans* can be used as an alternative to replace antibiotics in broiler chickens, facilitating similar performance and effectively controlling *Salmonella* Enteritidis. The results found are important in view of the growing demands of the chicken meat import market, especially in relation to possible contamination of the meat with antibiotic residues.

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