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Probiotics for Broiler Chickens in Brazil: Systematic Review and Meta-Analysis

Author(s)

Faria Filho DE[1]
Torres KAA[1]
Faria DE[2]
Campos DMB[1]
Rosa PS[1,3]

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1 Graduate student, Animal Science – Faculdade de Ciências Agrárias e Veterinárias. Universidade Estadual Paulista. Jaboticabal, SP, Brazil.
2 Professor, Faculdade de Zootecnia e Engenharia de Alimentos – Universidade de São Paulo. Pirassununga, SP, Brazil.
3 Researcher Embrapa Suínos e Aves (CNPSA), Professor, Universidade do Contestado (UnC). Concórdia, SC, Brazil.

Mail Address

Daniel Emygdio de Faria Filho
Via de acesso Paulo Donato Castellane, km 5, 14.884-900. Jaboticabal, SP, Brazil.

Email: fariafilho@hotmail.com

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ABSTRACT

This study evaluated the efficacy of probiotic utilization as growth promoters in broiler chicken feeding using systematic literature review and meta-analysis. Thirty-five studies were recovered by the systematic review, 27 of which met the following criteria to be included in the meta-analysis: (1) Brazilian studies published between 1995 and 2005; (2) probiotics administered in the diet without growth promoter; (3) results included performance data with the respective coefficient of variation. Meta-analysis have shown that the probiotics promoted better weight gain and feed conversion than the negative control (no antimicrobial) in the initial phase (1 to 20-28 days); nevertheless, results were similar in the total period (1 to 35-48 days). Weight gain and feed conversion were similar between probiotics and the positive control (with antimicrobial) both in the initial and in the total periods. Viability in the total period improved with the use of probiotics in comparison to the negative or positive controls. Sensitivity analysis showed that the results of meta-analysis were coherent. The funnel plots and the Egger regression method evidenced that the studies published in Brazil do not present biased results. It is possible to conclude that the probiotics are a technically viable alternative to antimicrobial growth promoters in broiler feeding. Nevertheless, further studies are necessary to identify eventual differences among the probiotics commercially available in Brazil.

INTRODUCTION

Antimicrobial growth promoters (antibiotics and chemotherapeutics) were largely used until December 2005 in commercial broiler rearing and have proved to be efficacious in improving productivity and animal health. Nevertheless, there is currently an increasing pressure towards the prohibition of such products, since it has been associated to induction of cross-resistance by pathogenic bacteria, cases of hypersensitivity reaction or even cancer by the presence of residues in meat (Menten, 2002). Therefore, the European Union, one of the major importers of poultry from Brazil, decided to prohibit the use of antimicrobial growth promoters in animal feeding after January 2006 (Council, 2003). Sweden and Denmark have already forbidden the use of antimicrobials in animal feeding. In Denmark, a report has shown poorer performance and a reduction of 2 to 3% in the profitability (Langhout, 2005).

In the last years, many alternatives to antimicrobial growth promoters have been studied, among which the use of probiotics, prebiotics, symbiotics, organic acids, enzymes, immunostimulants and herbal medicinal products.

Probiotics are defined as feed additives that contain live microorganisms and promote beneficial effects to the host by favoring the balance of the intestinal microbiota (Fuller, 1989). The term probiotic stems from the Greek and means "in favor of life"; its antonym is antibiotics, which means "against life" (Coppola & Turnes, 2004). Probiotics act by six different means (Menten, 2002): (a) adherence to the binding sites of the intestinal epithelium (competition with pathogenic bacteria); (b) direct antagonism through the production of bactericidal substances; (c) stimulus to the immune system; (d) facilitating the digestion and absorption of nutrients; (e) suppression of ammonia production, which might be toxic to intestinal cells; and (f) neutralization of enterotoxins.

Nevertheless, no matter the innumerous studies in the Brazilian literature about probiotics in broiler diets, performance results are not conclusive.

A consistent review of the studies about probiotics published up to date might be performed using the techniques of systematic literature review and meta-analysis. Systematic review consists of a scientific technique of reviewing the available literature, using explicit methods to identify, select and critically evaluate the studies that are relevant. Therefore, a previous search strategy must be defined, as well as the database, period of the review and inclusion criteria, among others. All these aspects must be enumerated in the final report. Besides, the studies that were not included in the review should be cited and their elimination should be justified. Therefore, systematic reviews are reproducible and are normally not biased.

The meta-analysis involves specific statistical methods that are applied to the systemic review to integrate the results of two or more studies, allowing to reach a conclusion about the issue that is being studied. It should include an analysis of sensitivity to evaluate the consistency of results. Additionally, analyses might be carried out to detect publication biases; for instance, only significant results are usually published (Wang & Bushman, 1999). A second possible bias is the publication of results that favor the utilization of specific commercial products.

The present study used the systematic review of the literature and meta-analysis to evaluate the efficacy of probiotic utilization as growth promoters in broiler feeding.

MATERIAL AND METHODS

Study period

Searches were performed in the first two weeks of May 2005.

Electronic searches were carried out using the keywords "probiotic", "growth promoter(s)" and "natural growth promoter(s)", associated with "broiler chickens" in the databases mentioned below. The keywords were translated to Portuguese before performing the searches in the first two databases ("probiótico(s)", "promotor(res) de crescimento", "promotor(res) natural(is) de crescimento" and "frangos de corte").

- **Scientific Electronic Library Online** (SCIELO) in the areas of Veterinary and Animal Science, involving the following Journals: Arquivo Brasileiro de Medicina Veterinária e Zootecnia (2004-1999), Brazilian Journal of Veterinary Research and Animal Science (2003-1998), Pesquisa Veterinária Brasileira (2004-1997), Pesquisa Agropecuária Brasileira (2005-2000), Revista Brasileira de Zootecnia (2004-2000), Ciência Rural (2005-2001) and Revista Brasileira de Zoologia (2005-2003).
- **ATHENA** (identifies the library collection of Faculdade de Ciências Agrárias e Veterinárias (FCAV/UNESP - Jaboticabal). Identification of dissertations, thesis and monographs published between 1995 and 2005 at that Institution, at Universidade Federal de Lavras (UFLA) and Faculdade de Zootecnia e Engenharia de Alimentos (USP).
- **CAB ABSTRACTS** (2005-1995).

Manual searches have included:

- **Periodicals:** Acta Scientiarum - Animal Science (2004-2002), ARS Veterinaria (2003-1998), Brazilian Journal of Poultry Science (2004-1999), Ciência Rural (2000-1995), Pesquisa Agropecuária Brasileira (1999-1995), Revista Brasileira de Zootecnia (1999-1995).
- **Meeting Annals:** Reunião Anual da Sociedade Brasileira de Zootecnia (2004-1995) and Conferência Apinco de Ciência e Tecnologia Avícolas (1999-1995).
- **Supplement of the Brazilian Journal of Poultry Science** (2005-2000).

These databases and periodicals were chosen because they comprise important sources of publications in the area of poultry production.

Inclusion criteria

The studies in the systematic review were selected based on the following inclusion criteria:

- Brazilian studies published between 1995 and 2005 that evaluated the effect of probiotics on the performance of broilers.

- Studies that used probiotics in diets without growth promoter(s) during the initial phase (1 to 20-28 days) and/or total period (1 to 35-48 days). It was also included studies that evaluated the addition of probiotics to the water or spray administration to one-day-old chicks, followed by administration in the diet.
- Studies that indicated weight gain, feed conversion and/or rearing viability (or mortality) together with the coefficient of variation of the averages.

Data collection

The reviewers collected data concerning weight gain, feed conversion and/or rearing viability (or mortality) of the positive control (with antimicrobial) and/or negative control (without antimicrobial), and for the diets that had been supplemented with probiotic. The coefficients of variation and overall mean of each variable were recorded. Overall means that were not explicitly presented were then calculated. It was also collected information about the type, administration route and dosage of probiotic, the number of replicates per treatment, the number of birds per replicate, housing type (floor, cage or batteries), broiler age, strain, gender, addition of anti-coccidiosis chemicals and the drug supplemented in the positive control.

In the experiments that evaluated different doses of the same probiotic, the dosage that produced better results was considered. On those studies involving the comparison of more than one positive control with diets containing probiotic, it was considered the result of the best positive control.

Statistical analysis

The meta-analysis considered only the probiotic that was evaluated in two or more than two independent studies.

The effect size (Effect) was calculated for each study:

Effect = mean of the group fed probiotic - mean of control group/ overall standard deviation

The overall standard deviation was obtained by multiplying the coefficient of variation (divided by 100) by the overall mean of the experiment. Afterwards, the effect size was transformed into the unbiased effect size (Hedges) by multiplying it with a correction factor (Hedges, 1982).

An analysis was carried out to assess the existence of outliers, normality assumption (Shapiro-Wilk test) and variance homogeneity (Chi-square test). After these assumptions were assured, the effect sizes were combined so that each study was given different weights based on the inverse variance method, i.e., the studies with more replicates were given greater weights. Therefore, it was used a randomized model that considered the probiotic type as classifying variable. Meta-analyses were carried out separately based on the control type (negative or positive), age (initial phase or total period), and variables (weight gain, feed conversion and rearing viability). A confidence interval of 95% was calculated for each combined size effect.

Sensitivity analysis was then performed to assess the robustness of meta-analysis results. It consisted in performing the same analysis including the studies without repetitions as a separate group of probiotics. Outliers, and the assumptions of variance homogeneity and normality were verified.

A funnel graph was plotted and Egger's regression (Egger *et al.*, 1997) was used to evaluate the existence of publishing bias. In the funnel graph, the effect sizes were plotted as a function of the inverse of variance. Egger's regression is a simple linear regression where the size effects divided by their standard error are considered as the dependent variable and the inverse of variance as the independent variable (Egger *et al.*, 1997).

All analyses were carried out using SAS® (Wang & Bushsman, 1999).

RESULTS

Systematic review

It was identified 35 studies about the effects of probiotics on the performance of broilers in Brazil. The studies were published between 1995 and 2000.

Eight studies have not met the inclusion criteria, as follows: the coefficient of variation was not mentioned (Leandro *et al.*, 2003 a; Rangrab *et al.*, 2004; Sugeta *et al.*, 2004; Wolke *et al.*, 1996); the probiotic was administered only in the drinking water (Boratto *et al.*, 2004); the probiotic was administered in conjunction with antibiotics (Lima *et al.*, 2003); the probiotic was administered only during the growth period (Araújo *et al.*, 2000); and there was no table indicating performance results (Schwarz *et al.*, 2002).

Some studies tested more than one type of probiotic, so that some treatments did not meet the inclusion criteria: only spray administration of probiotic (Leandro *et al.*, 2001), and probiotic administered only via drinking water (Pedroso *et al.*, 2003; Pelicano *et al.*, 2004 b; Teixeira *et al.*, 2003).

The remaining 27 studies meet the criteria and involved 30,146 broiler chickens. These studies have been published as follows: 14 scientific articles, one PhD thesis, three Master dissertations, two monographs, five expanded abstracts and two abstracts in scientific journals. Some studies have been published in more than one of these forms. Nevertheless, they have been considered only once, according to the following criterion of priority: (1) scientific articles, (2) thesis, dissertations and monographs, (3) expanded abstracts, and (4) abstracts in scientific journals. Cavalvanti (1995) and Teixeira *et al.* (2003) correspond to the same study, although the latter have not presented the viability data that was shown in the first one.

The studies meeting the inclusion criteria have used 12 different probiotics:

A) *Lactobacillus reuteri* and *Lactobacillus jonhsonii* in the drinking water at one day of age + *Bacillus subtilis* in the diet (Loddi, 2003; Pedroso *et al.*, 2003; Sato, 2001; Schocken-Iturrino *et al.*, 2004; Vargas Júnior *et al.*, 2001).

B) *Bacillus subtilis* in the diet (Campos, 2002; Correa *et al.*, 2003 a,b; Henrique, 1998; Leandro *et al.*, 2001; Leandro *et al.*, 2003 b; Lima *et al.*, 2002; Loddi *et al.*, 2000 b; Maiorka *et al.*, 2001; Pelicano *et al.*, 2004 a,b).

C) *Lactobacillus acidophilus*, *Lactobacillus casei*, *Streptococcus salivarium*, *Streptococcus faecium*, *Bacillus subtilis*, *Bacillus toyoi* and *Saccharomyces cerevisiae* in the diet (Correa *et al.*, 2003 a,b; Laurentiz, 2000).

D) *Lactobacillus acidophilus*, *Lactobacillus casei*, *Streptococcus lactis*, *Streptococcus faecium*, *Bifidobacterium bifidum* and *Aspergillus oryzae* in the diet (Pelicano *et al.*, 2004 a; Santos *et al.*, 2004 a,b).

E) *Saccharomyces cerevisiae* in the diet (Pedroso *et al.*, 2003; Pelicano *et al.*, 2004 b).

F) *Enterococcus faecium*, *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* in the diet (Cavalcanti, 1995; Henrique, 1998; Teixeira *et al.*, 2003).

G) *Bacillus toyoi* in the diet (Zuanon *et al.*, 1998 a,b Hedges, 1982).

H) *Bacillus subtilis* and *Bacillus licheniformis* in the diet (Pelicano *et al.*, 2004 b; Santos *et al.*, 2004 c).

I) *Pediococcus acidilactici* in the diet (Leandro *et al.*, 2005).

J) *Enterococcus faecium* in the diet (Loddi *et al.*, 2000 a).

K) *Enterococcus faecium*, *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* in the drinking water at one day of age and then in the diet throughout the experimental period (Silva *et al.*, 2000).

L) *Lactobacillus reuteri* and *Lactobacillus jonhsonii* via spray at one day of age + *Bacillus subtilis* in the diet (Leandro *et al.*, 2001).

Meta-analysis

Meta-analyses were performed for the studied probiotics in more than one study (probiotics from A to H).

Meta-analysis results are presented in Tables 1, 2, 3 and 4. Outliers were not identified and the normality assumption was met in all cases. Probabilities associated to the test of variance homogeneity were presented with the meta-analyses. In some cases, the heterogeneity of variances ($p<0.05$) prevented the combination of the studies.

The effect size (Hedges, 1982) of each probiotic and of the group of probiotics was calculated for the studies showing homogeneity of variances ($p>0.05$). The effect sizes greater than zero for weight gain and rearing viability and lower than zero for feed conversion indicate results favorable to the utilization of probiotics. The confidence interval (95%) was calculated for each effect size. The effect sizes with confidence intervals containing the number zero were not significantly different from zero, i.e., there were no significant differences between the control (negative or positive) and the probiotic.

The meta-analyses performed with data from the initial period compared the probiotics with negative controls and are shown in Table 1. The comparison of individual probiotic showed no differences between the utilization of probiotic or the negative control on the performance of broilers, except for probiotic C. This probiotic has improved feed conversion in comparison to the negative control. On the other hand, when considering the group of probiotics (overall results), their utilization have significantly improved weight gain, feed conversion and rearing viability.

The comparisons between probiotics and negative control in the total period are shown in Table 2. Probiotic A increased weight gain, whereas probiotics B to G and the overall results resulted in similar weight gain and feed conversion in comparison to the negative control. Rearing viability was better with probiotics B, F and overall results.

Table 1 - Meta-analysis comparing probiotics and negative control on broiler performance during the initial phase.

Probiotics	n	Hedges	Confidence interval 95%		Homogeneity
			Lower	Upper	(p value)
Weight gain					
A	6	0.52	-0.04	1.08	0.86
B	10	0.28	-0.10	0.67	0.40
C	2	0.33	-0.66	1.31	0.37
D	2	-	-	-	0.03
E	3	0.23	-0.50	0.96	0.76
F	3	0.06	-0.52	0.64	0.24
G	2	0.03	-0.87	0.94	0.13
Overall	26	0.27	0.03	0.51	0.90
Feed conversion					
A	6	-0.58	-1.22	0.07	0.96
B	10	-0.38	-0.85	0.09	0.17
C	2	-1.53	-2.75	-0.31	0.74
D	2	-	-	-	0.03
E	3	-0.17	-1.05	0.72	0.08
F	3	-0.14	-0.88	0.59	0.86
G	2	0.07	-0.99	1.13	0.31
Overall	26	-0.39	-0.68	-0.10	0.40
Rearing viability					
A	3	0.40	-0.57	1.37	0.15
B	2	0.72	-0.42	1.86	0.06
E	2	0.92	-0.22	2.05	0.96
F	3	0.33	-0.45	1.11	0.94
Overall	10	0.52	0.04	1.01	0.83

n = number of studies. Hedges = combined effect size for n studies = [(probiotic mean - negative control mean)/ overall standard deviation]* correction factor. Probiotics: A) *Lactobacillus reuteri* and *Lactobacillus jonhsonii* in drinking water on the first day + *Bacillus subtilis* in the diet. B) *Bacillus subtilis* in the diet. C) *Lactobacillus acidophilus*, *Lactobacillus casei, Streptococcus salivarium*, *Streptococcus faecium*, *Bacillus subtilis*, Bacillus toyoi and *Saccharomyces cerevisiae* in the diet. D) *Lactobacillus acidophilus*, *Lactobacillus casei, Streptococcus lactis*, *Streptococcus faecium*, *Bifidobacterium bifidum* and *Aspergillus oryzae* in the diet. E) *Saccharomyces cerevisiae* in the diet. F) *Enterococcus faecium*, *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* in the diet. G) *Bacillus toyoi* in the diet.

Table 2 - Meta-analysis comparing probiotics and negative control on broiler performance during the total rearing period.

Probiotics	n	Hedges	Confidence interval 95%		Homogeneity
			Lower	Upper	(p value)
Weight gain					
A	4	0.95	0.22	1.68	0.85
B	9	0.18	-0.26	0.62	0.41
C	2	-0.21	-1.21	0.79	0.40
D	2	0.28	-0.50	1.06	0.58
E	2	-0.47	-1.40	0.46	0.95
F	2	-0.02	-0.76	0.72	0.32
G	2	0.17	-0.74	1.07	0.28
H	2	-0.33	-1.12	0.58	0.17
Overall	25	0.14	-0.12	0.41	0.34
Feed conversion					
A	4	-0.55	-1.15	0.06	0.95
B	9	0.04	-0.33	0.40	0.06
C	2	-0.01	-0.90	0.88	0.26
D	2	-0.56	-1.19	0.08	0.59
E	2	-	-	-	0.02
F	2	-0.14	-0.70	0.43	0.64
G	2	-0.23	-1.00	0.55	0.54
H	2	0.77	-0.06	1.60	0.06
Overall	21	-0.10	-0.34	0.14	0.22
Rearing viability					
A	2	0.82	-0.17	1.82	0.47
B	4	0.81	0.23	1.38	0.25
E	2	0.32	-0.55	1.18	0.49
F	2	0.93	0.23	1.64	0.32
Overall	10	0.76	0.39	1.12	0.74

n = number of studies. Hedges = combined effect size for n studies = [(probiotic mean - negative control mean)/overall standard deviation]*correction factor. Probiotics: A) *Lactobacillus reuteri* and *Lactobacillus jonhsonii* in drinking water on the first day of age + *Bacillus subtilis* in the diet. B) *Bacillus* subtilis in the diet. C) *Lactobacillus acidophilus*, *Lactobacillus casei*, *Streptococcus salivarium*, *Streptococcus faecium*, *Bacillus subtilis*, *Bacillus toyoi* and *Saccharomyces cerevisiae* in the diet. D) *Lactobacillus acidophilus*, *Lactobacillus casei*, *Streptococcus lactis*, *Streptococcus faecium*, *Bifidobacterium bifidum* and *Aspergillus oryzae* in the diet. E) *Saccharomyces cerevisiae* in the diet. F) *Enterococcus faecium*, *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* in the diet. G) *Bacillus toyoi* in the diet. H) *Bacillus subtilis* and *Bacillus licheniformis* in the diet.

Meta-analyses that compared the probiotics with the positive control are shown in Table 3 (initial phase) and Table 4 (total period). In the initial period, weight gain, feed conversion and rearing viability were not different from the positive control (individual or overall). In regard to weight gain in the total period, it was not possible to calculate the size of effect for the group of probiotics as a function of the heterogeneity of variances. Nevertheless, probiotic C increased weight gain, whereas the others showed similar weight gain and feed conversion in comparison to the positive control. Rearing viability improved with the utilization of probiotic F.

Table 5 shows the overall performance results in the initial and overall periods in comparison to the negative controls or positive controls with probiotics, for the set of studies included in the meta-analysis.

Sensitivity analysis

The sensitivity analysis was performed to evaluate the robustness of the overall meta-analysis results (group of probiotics). Therefore, the meta-analysis was carried out again including the probiotics from I to L as a single probiotic.

Loddi *et al.* (2000 a) compared the effects of probiotics and a negative control on the weight gain in the initial phase. This study was considered an outlier and was not included in this analysis. There were no outliers in the other cases and both assumptions of normality and homogeneity of variances have been met.

The sensitivity analysis did not change the overall results of the meta-analyses for both periods (initial or total) and the studied variables (weight gain, feed conversion and rearing viability).

Publication bias

In this analysis, the feed conversion in the total period compared probiotic with the positive control (high bias potential) was used. The studies included in the sensitivity analysis have been also included. A possible bias would be omitting studies in which the results were unfavorable to the probiotic utilization. A second possible bias would be the publication of significant results only. In the funnel graph (Figure 1), the studies with lower precision showed great dispersion (large basis) and the results funneled towards the estimate value of the effect size with increasing precision (Hedges = 0.04 for feed conversion, Table 5). According to the Egger's regression, the intercept was zero (p=0.68), which indicated that the funnel graph have not shown asymmetry. Such results suggested that the Brazilian studies that evaluated the probiotic effects on the performance of broiler chickens did not show publication bias.

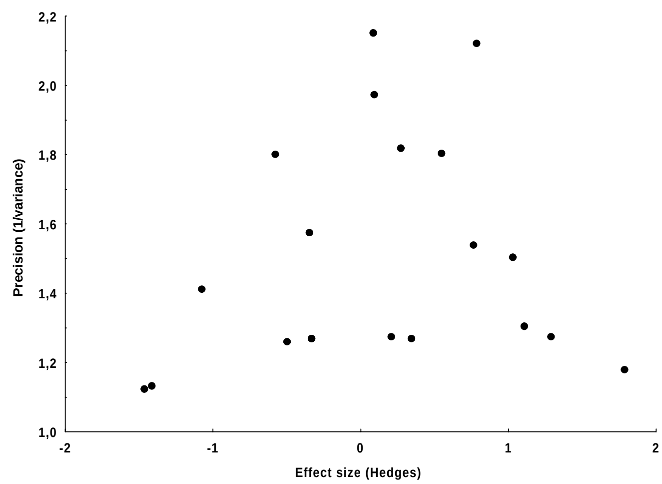

Figure 1 – Funnel graph for the effect sizes for feed conversion comparing probiotics to the positive control in the total period.

DISCUSSION

The individual comparisons of the probiotics with the negative control in the initial period did not show difference between these treatments (except for probiotic C for feed conversion). Nevertheless, when the analysis was performed considering a group, a beneficial effect was observed with the utilization of probiotic. Such difference occurred as a function of the increase in the number of observations and consequently decreased the confidence interval. These results evidenced that probiotic improved performance when compared to a diet without antimicrobial growth promoters; however, it is not possible to identify if there are differences between the probiotics commercially available in Brazil.

Nevertheless, it is worth noting that there was a tendency of improvement in the performance in the initial period when the probiotic A was used in comparison to the negative control (if a confidence interval of 94% had been used, the result would have been significant) and such difference increased in the total period in favor of probiotic A. On the other hand, it was not possible to compare Probiotic A with the positive control in the total rearing period because there were no repetitions, which prevents from a precise inference in regard to the effectiveness of this probiotic when used alone.

Table 3 - Meta-analysis comparing probiotics and positive control on the performance of broilers during the initial phase.

Probiotics		n	Hedges	Confidence interval 95% Lower	Confidence interval 95% Upper	Homogeneity (p value)
Weight gain						
	A	2	-0.67	-1.72	0.37	0.41
	B	6	0.47	-0.06	0.99	0.43
	C	2	0.74	-0.33	1.81	0.10
	F	2	-0.29	-1.05	0.47	0.45
	G	2	-0.60	-1.54	0.33	0.57
Overall		14	0.07	-0.28	0.41	0.08
Feeding conversion						
	A	2	-0.07	-1.46	1.32	0.41
	B	6	0.19	-0.58	0.96	0.26
	C	2	-	-	-	0.01
	F	2	0.16	-1.04	1.37	0.41
	G	2	1.20	-0.18	2.58	0.28
Overall		12	0.30	-0.24	0.84	0.56
Rearing viability						
	F	2	0.47	-0.66	1.60	0.32
Overall		2	0.47	-0.66	1.60	-

n = number of studies. Hedges = combined effect size for n studies = [(probiotic mean - positive control means)/ overall standard deviation] * correction factor. Probiotics: A) *Lactobacillus reuteri* and *Lactobacillus jonhsonii* in drinking water on the first day of age + *Bacillus subtilis* in the diet. B) *Bacillus subtilis* in the diet. C) *Lactobacillus acidophilus*, *Lactobacillus casei*, *Streptococcus salivarium*, *Streptococcus faecium*, *Bacillus* subtilis, *Bacillus toyoi* and *Saccharomyces cerevisiae* in the diet. F) *Enterococcus faecium*, *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* in the diet. G) *Bacillus toyoi* in the diet.

Table 4 - Meta-analysis comparing probiotics and positive control on the performance of broilers in the total period.

Probiotics		n	Hedges	Confidence interval 95%		Homogeneity
Weight gain						
	B	6	0.34	-0.13	0.80	0.20
	C	3	0.83	0.33	1.33	0.48
	F	2	-0.27	-0.84	0.30	0.96
	G	2	-0.47	-1.25	0.31	0.88
Overall		13	-	-	-	0.01
Feeding conversion						
	B	6	-0.04	-0.73	0.65	0.48
	C	3	-0.13	-1.05	0.80	0.15
	F	2	-0.02	-1.05	1.02	0.28
	G	2	0.57	-0.60	1.74	0.73
Overall		13	0.04	-0.41	0.48	0.81
Rearing viability						
	F	2	0.66	0.08	1.24	0.65
Overall		2	0.66	0.08	1.24	-

n = number of studies. Hedges = combined effect size for n studies = [(probiotic means - positive control means)/ overall standard deviation]* correction factor. Probiotics: B) *Bacillus subtilis* in the diet. C) *Lactobacillus acidophilus*, *Lactobacillus casei*, *Streptococcus salivarium*, *Streptococcus faecium*, *Bacillus subtilis*, *Bacillus toyoi* and *Saccharomyces cerevisiae* in the diet. F) *Enterococcus faecium*, *Lactobacillus acidophilus* and *Saccharomyces cerevisiae* in the diet. G) *Bacillus toyoi* in the diet.

Table 5 - Performance of broiler chickens fed probiotics or control diets, in the initial phase and in the total rearing period, in the studies assessed by meta-analysis.

	Weight gaing	Feed conversiong/g	Rearing viability%
Initial phase			
Negative control	739.4±30.6 (n=26)	1.514±0.030 (n=26)	95.2±1.06 (n=10)
Probiotics	746.9±30.6 (n=26)	1.493±0.032 (n=26)	97.5±0.39 (n=10)
Positive control	687.3±32.3 (n=13)	1.498±0.043 (n=12)	97.8±0.70 (n=2)
Probiotics	688.4±31.6 (n=13)	1.510±0.053 (n=12)	98.5±0.25 (n=2)
Total period			
Negative control	2243.9±63.3 (n=23)	1.871±0.026 (n=23)	92.3±1.02 (n=10)
Probiotics	2248.3±65.0 (n=23)	1.867±0.026 (n=23)	94.9±0.85 (n=10)
Positive control	2095.8±76.0 (n=13)	1.862±0.032 (n=13)	94.6±0.40 (n=2)
Probiotics	2112.6±73.8 (n=13)	1.858±0.037 (n=13)	96.0±0.10 (n=2)

Means weighed using the inverse of variance ± standard error of the mean (SEM). n = number of observations.

In the total period, probiotic C significantly improved the body weight gain compared to the positive control; however, this improvement was not seen in the initial period. In the initial period, two studies were used in the comparison (Correa *et al.*, 2003 a,b) and, in the total period, three studies (Correa *et al.*, 2003 a,b; Laurentiz, 2000). The removal of Laurentiz (2000) from the meta-analysis of the total period resulted in a similar weight gain of Probiotic C and positive control, indicating a lack of robustness of this result that favored Probiotic C.

The results of sensitivity analysis did not modify the overall results of meta-analysis, indicating that the results, without distinction between probiotics, are consistent. Another important point that corroborates the overall results was the absence of publication bias evidenced by the funnel graph and the Egger's regression.

It was observed five cases of heterogeneity of variance. Such heterogeneities might have occurred as a function of methodological differences among the studies, such as administration dosage of the probiotic, number of birds per repetition, installation type, strain, gender, inclusion of anti-coccidiosis chemicals, challenge of birds with pathogens and drug used in the diet of the positive control. Although all these data have been collected, it was not possible establish a statistical model including all variables.

Furthermore, as discussed by Menten & Pedroso (2005), it is necessary to consider the composition of probiotic commercialized in regard to identity and microbial concentration. These authors found evidences in the literature and in a study of their own that not always the indicated composition in the probiotic is the one that is comprised by the product.

CONCLUSIONS

It may be concluded that the probiotics are a technically viable alternative to antimicrobial growth promoters in broiler feeding. Nevertheless, further studies are needed to identify eventual differences among the probiotics commercially available in Brazil.

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