



# Supplementation of Antibiotic Growth Promoters versus Supplementation of Functional Oils in Broiler Breeders: Performance and Offspring Effects

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## ■ Keywords

Broiler breeders, functional oils, growth promoters, offspring effects.



## ABSTRACT

The effects of either functional oil or antibiotic growth promoter supplementation on broiler breeders and their offspring were assessed in 2 experiments. In Experiment I, 16,400 broiler breeders (22 weeks old) were distributed into 2 experimental groups, one supplemented with 1,500 ppm of a commercial blend of functional oils (active ingredients: cashew nutshell liquid and castor oil) and the other with 500 ppm of bacitracin methylene disalicylate (BMD). Laying rates, fertility, embryonic mortality, and egg characteristics were measured from weeks 25 to 46. In Experiment II, 720 one day old male chicks, born from 42 week old breeders, from each one of the two treatments in Experiment I, were supplemented with either 10 ppm of enramycin or 1,500 ppm of the same functional oils as in Experiment I to study whether there were any maternal diet carry-over effects. Functional oils decreased embryonic mortality from 11.01% to 9.64% ( $P < 0.03$ ) when compared to BMD. However, a functional oil link increase in egg weight did not result in either heavier chicks or statistically significant better offspring performance. Nonetheless, a possible benefit of the functional oil supplementation on the offspring weight at 42 d cannot be excluded. The type of additive supplemented during Experiment II did not affect any performance parameters. In conclusion, functional oils could successfully replace antibiotic growth promoters in broiler breeders as embryonic mortality decreased. Finally, when functional oils were supplemented to the offspring, the performance was similar to that of a commonly used antibiotic growth promoter.

## INTRODUCTION

The use of antibiotic growth promoters is a widespread strategy to increase broiler breeder performance. The expected improvements are supposed to be derived from a better utilization of the limited feed allowance (Bozkurt *et al.*, 2009). However, antibiotic growth promoters have been banned in the European Union since 2006, and most countries are implementing either total or partial bans on their use. Therefore, viable alternatives are needed to maintain productivity.

Nutritional, pathological, and environmental factors have been shown to increase free radical production in broiler breeders (Birendra and Jha, 2019; Hu *et al.*, 2019). Free radicals negatively affect fertility and hatchability (Breque *et al.*, 2003; Pappas, 2005) and the supplementation of antioxidants has been shown to counteract these negative effects (Rosa *et al.*, 2012) and improve embryonic development (Surai *et al.*, 2019). Whereas some functional oils such as cashew nut shell liquid have been shown to have antioxidant activity (Trevisan *et al.*, 2005), others, like castor oil have been shown to be anti-inflammatory (Vieira *et al.*, 2001) and have activity against some fungi and gram positive bacteria (Novak *et al.*, 1961). It is probably because all of these



activities that a commercial mixture of cashew nut shell liquid and castor oil has been shown to reduce inflammation in coccidiosis challenged birds (Moraes *et al.*, 2019) and the negative effects of heat stress (Torrent *et al.*, 2019). Also, functional oils have been shown to increase energy utilization in broiler diets (Bess *et al.*, 2012; Murakami *et al.*, 2014). Because of all these effects, functional oils should favorably affect the breeder's reproductive parameters or, at least, yield performance results similar to those of antibiotic growth promoters.

Supplementation of functional oils may also affect offspring performance. For example, Koedijk *et al.*, (2015) showed that chick weight was significantly heavier at hatch and that average daily gain improved significantly in young breeder offspring when supplemented with polyphenols, which are known antioxidants. Therefore, the objective of this paper is: 1) to compare the performance of broiler breeders supplemented with either an antibiotic growth promoter or a commercial blend of functional oils (active ingredients: cashew nut shell liquid and castor oil), 2) to evaluate whether these effects carried over to the offspring performance, 3) to evaluate how the supplementation with either functional oils or antibiotic growth promoters affected broiler performance, and 4) to study whether there was an interaction between the maternal and the offspring supplementation that affected performance.

## **MATERIALS AND METHODS**

### **Experiment I**

All the procedures used in this experiment were approved by the Universidade Federal do Paraná in Palotina Animal Care Committee and were in accordance with the guidelines outlined by the University Animal Care Committee.

### **Animals**

A total of 16,400 broiler breeders and 1,722 roosters (22 week old), from a commercial poultry integrator, were randomly assigned to two different bird houses (8,200 breeders and 861 roosters each) in the same breeder complex. Historically, both houses had previously been shown to consistently yield non significant different results in breeder performance. The birds were distributed at 23 weeks of age into 2 experimental groups with similar body weight and uniformity and were reared following the guidelines of Aviagen for Ross AP 95 broiler breeders.

### **Feed and experimental additives**

Birds were fed corn-soybean-based mash diets (Table 1). The supply of the feed was strictly controlled, in accordance with the recommendations of the breeder company. One group received 1,500 ppm of a commercial blend of two functional oils, cashew nut shell liquid and castor oil (active components in the commercial product: 20% cardanol and 5% cardol from cashew nut shell liquid and 9% ricinoleic acid from castor oil; Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil) supplemented in the diet using expanded vermiculite as a carrier, and the second group received the diet supplemented with 500 ppm of bacitracin methylene disalicylate (BMD). Roosters in both groups received the same diet, which was also supplemented with 500 ppm of BMD. During the whole period, the same male:female ratio was maintained in both houses.

### **Housing of birds, collection and incubation of eggs**

The birds were placed in houses using negative pressure ventilation, with wood shavings litter floors, equipped with automatic drinkers, tube feeders for the hens, and a trough-type feeder for the roosters. Water was supplied for ad libitum consumption, and a photoperiod of 16L:8D was used during the study.

The laying rate was calculated weekly as the number of eggs produced per breeder per week per group divided by 7 and was measured from week 26 till week 46 of age. A total of 5,040 hatching eggs per treatment were collected on weeks 26, 30, 34, 38, 42, and 46.

The incubation was performed in a commercial hatchery, in single-stage incubators, following company standards. Trolleys were identified and the eggs were incubated for 48 h and at that point, fertility was evaluated using the automatic vaccination scanner machine. At 18 days of incubation, the *in ovo* vaccination was performed for infectious bursal disease and Marek's disease, and the machine automatically removed and counted infertile eggs. Eggs previously vaccinated and therefore considered fertile were transferred to the hatchers in identified trays, where they remained until the 21st day of incubation. On the 21st day of incubation after hatching, the total number of viable chicks and total non-hatched eggs per tray were counted in each treatment. Fertility was calculated based on the number of infertile eggs (removed by the vaccinating machine) according to the total number of eggs incubated on each floor of



**Table 1** – Ingredients and nutritional composition of the breeder diets in Experiment I.

Ingredients, %	Wk 24 - 42		Wk 42 - 46	
	BMD <sup>1</sup>	Functional Oils	BMD	Functional Oils
Corn	63.74	63.74	71.41	71.42
Soybean oil	1.77	1.77	-	-
Soybean meal	19.33	19.33	19.08	19.08
Wheat midds	6.00	6.00	-	-
Dicalcium phosphate	1.09	1.09	1.05	1.05
Salt	0.25	0.25	0.25	0.25
DL-Methione	0.10	0.10	0.10	0.10
Choline chloride	0.12	0.12	0.10	0.10
Sodium bicarbonate	0.12	0.12	0.12	0.12
Limestone	4.00	4.00	3.83	3.83
Limestone, 5 mm	2.05	2.05	2.77	2.77
BMD	0.05	-	0.05	-
Functional oils	-	0.15	-	0.15
Vitamin-mineral premix <sup>2</sup>	0.50	0.50	0.50	0.50
<b>Nutritional composition</b>				
Metabolizable Energy, kcal/kg	2,850		2,850	
Crude Protein, %	15.00		14.50	
Ether Extract, %	4.46		2.81	
Linoleic acid, %	2.20		1.29	
Ca, %	2.80		3.00	
Available P, %	0.40		0.38	
Digestible Lys, %	0.658		0.637	
AAS dig, %	0.542		0.534	
Digestible threonine, %	0.487		0.477	
Digestible triptophne, %	0.153		0.144	
Digestible leucine, %	1.218		1.229	
Digestible isoleucine, %	0.566		0.555	
Digestible arginine, %	0.879		0.843	
Choline, mg/kg	1,592.20		1479.02	
Na, %	0.171		0.170	
Cl, %	0.221		0.217	
K, %	0.668		0.617	
Na+K+Cl meq/100g	182.99		170.75	

<sup>1</sup>Bacitracin methylene disalicylate.

<sup>2</sup>Vitamin premix (Content per kg of premix): Vitamin A 3,200 UI; Vitamin D3: 900 UI; Vitamin E: 32,000 mg; Vitamin K3: 1,000 mg; Vitamin B1: 1,000 mg; Vitamin B2: 2,400 mg; Vitamin B6: 1,600 mg; Vitamin B12: 8,000,40 µg; Niacin: 13,000 mg; Pantothenic acid: 4,000 mg; Folic acid: 800 mg; Biotin: 79,992mcg; Antioxidant: 13,320. Mineral premix (Content per kg of premix): Cobalt: 100,10 mg; Iron: 12,000 mg; Copper: 4,000 mg; Iodine: 400 mg; Zinc: 28,000 mg; Manganese: 26,000 mg; Selenium: 80mg; Phytase 100,000 FTU.

the egg trolley. Hatching was based on the number of chicks born according to the total number of incubated eggs. On weeks 25, 33, 41, and 49, 45 eggs per treatment were individually evaluated to determine the weight, specific gravity (determined by the flotation method using increments of .001), yolk weight, albumen weight, and shell weight and thickness. To measure the shell weight, the shells were washed and dried at room temperature for 72 h and were weighed using a precision digital scale (0.001 g). After weighing the shells, the shell thickness was measured at 3 points in the central region of each shell using a digital micrometer (Mitutoyo Sul Americana, São Paulo, Brazil). To evaluate the hatching rate of fertile eggs, fertility, and embryonic mortality, the non

hatched eggs were submitted to embryo diagnostics. In this evaluation, the eggs were classified through a macroscopic visual examination as infertile; embryonic mortality at the first 72 h of incubation; embryonic mortality occurring between days 4 and 10 of incubation; embryonic mortality occurring between days 11 and 17 of incubation; embryonic mortality occurring between days 18 and 21 of incubation, including dead-pipped embryos; and pipped eggs that have broken the shell but not emerged at the time of removal of chicks from the hatcher and the embryo is still alive. Eggs with abnormal contents with green or black coloration and emitting rotten odors or eggs that exploded on opening were considered contaminated.



### **Experimental Design and Statistical Analysis**

Laying rates (%) for both treatments were modeled according to the modified compartment logistic curvilinear model following the equation:

$$y(t) = ae^{-bt}/[(1+e^{-c(t-d)})] \text{ (Yang et al., 1989)}$$

Where,  $a$  = a scale parameter,  $b$  = the rate of decrease in laying ability,  $c$  = the reciprocal indicator of the variation in sexual maturity, and  $d$  = the mean age of sexual maturity of the hens.

The comparison of the laying rates was done comparing the full logistic curvilinear model that used different coefficients for each treatment, to the reduced model that used the same coefficients for both treatments. This comparison is performed using the extra sum of squares that provide a means of formally testing whether one set of predictors (full model) is necessary given that another set is already in the model (reduced model). The method works by looking at the reduction in the residual sum of squares when the set of additional variables is added to the model. This change is divided by the number of degrees of freedom for the additional variables to produce a mean square. This mean square is compared to the residual mean square from the full model. The 2 models, one using just one set of logistic coefficients for both treatments and the other one using a different set of logistic coefficients for each treatment, were then compared using an F-statistic. (R packaged version 1.5.2).

It was not possible to directly calculate the relative number of chicks/breeder/day, as the different reproductive parameters were taken from samples and not from the total population of the birds studied. Therefore, a bootstrapping technique was used to obtain the average percent of chicks/breeder/day during the period of the test and to compare the two treatments using Monte Carlo methods (Efron & Tibshirani, 1993). The model was iterated 100,000 times, using a program written in Python, to obtain and compare the mean of the percentage number of chicks/breeder/day.

Laying rate, hatching rate, fertility, weekly mortality, embryonic mortality, contaminated and cracked eggs, and all the egg characteristics were the dependent variables. The independent variables were treatment and week of age. An analysis of variance with week as the repeated measure and treatment as the fixed factor was used to assess the reproductive and egg parameters differences (R packaged version 1.5.2). As percentage data are not normal they were arcsine-transformed before analysis to achieve normality.

### **Experiment II**

This research was conducted at the Experimental Agronomic Station of the Federal University of the State of Paraná, in Palotina, Brazil, with the approval of the Institutional Animal Care and Use Committee, which oversees research with animals and poultry at university facilities.

#### **Birds and Housing**

A total of 720 one day old male chicks, born from 42 week old breeders, from each one of the two treatments in Experiment I, were assigned to either a treatment using 10 ppm of enramycin or a treatment using 1,500 ppm of functional oils (Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil) as growth promoters. The birds were housed in a climate controlled house (exhaust fans, evaporative cooling pads, and brooder heaters), divided into 36 boxes of 3.52 m<sup>2</sup>, covered with reused litter. The thermal comfort temperature was maintained according to the age using a 300 W halogen lamp heating system. The birds received 24 hours of light from day 1 to day 21, and 16 hours of light and 8 of dark from day 21 till the end of the experiment. The experiment included a starter (1-21 days), a grower (22-35 days), and a finisher diet (36-42 days). The nutrient levels of the diets followed typical Brazilian industry standards (Table 2).

#### **Experimental Design and Statistical Analysis**

A 2 x 2 ANOVA with 2 breeder effects and 2 offspring effects (supplementation with either antibiotic growth promoters or with functional oils in both cases) was used to study treatment differences (R packaged version 1.5.2). Percentage data were arcsine-transformed before analysis to achieve normality.

## **RESULTS AND DISCUSSION**

### **Experiment I**

The comparison of the logistic curvilinear full model (including a different set of coefficients for each treatment) to the reduced model (including just one set of coefficients) showed that the full model was not superior to the reduced one and that, therefore, there were no differences for the laying rates between treatments. The equation obtained for the reduced model was (Figure 1):

$$y(t) = 125.94e^{-0.012t}/[(1+e^{-1.71(t-24.62)})]$$

Showing that birds reached sexual maturity at approximately 25 weeks of age and that the rate of decrease in laying ability was 1.2%/week, both values



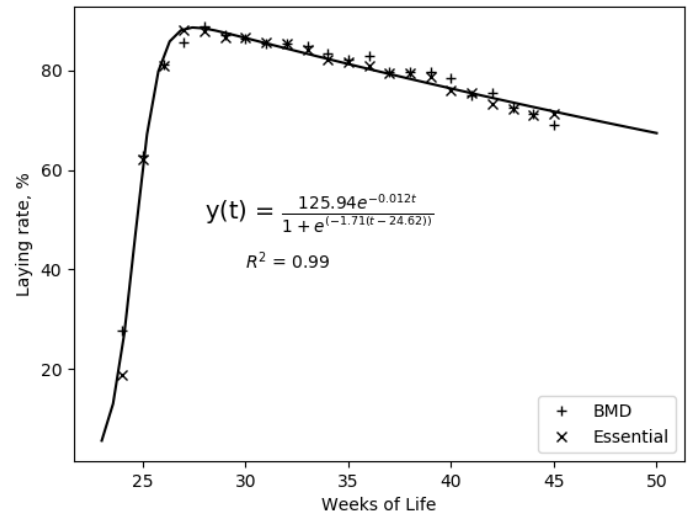
**Table 2** – Ingredients and nutritional composition of the offspring diets of Experiment II.

Ingredients, %	Starter	Grower	Finisher
Corn	58.58	63.2	66.31
Soybean Oil	1.30	1.20	1.80
Soybean Meal	36.10	32.00	28.60
Dicalcium Phosphate	1.16	1.08	0.94
Salt	0.35	0.42	0.40
DL-Methionine	0.29	0.24	0.22
Sodium Bicarbonate	0.20	-	-
L-Threonine	0.09	0.09	0.06
Kaolin <sup>1</sup>	0.15	0.15	0.15
Limestone	1.00	0.84	0.82
Vitamin and mineral premix <sup>2</sup>	0.30	0.30	0.30
Lysine - HCL	0.37	0.36	0.32
Choline Chloride	0.06	0.07	0.08
Anticoccidial	0.05	0.05	-
Nutrient levels			
Metabolizable energy, Kcal/kg	2980	3050	3125
Crude Protein, %	21.93	20.36	18.96
Ether Extract, %	3.73	3.72	4.36
Crude Fiber, %	3.22	3.06	2.91
Ashes, %	6.12	5.44	5.06
Calcium, %	0.94	0.85	0.79
Available phosphorus, %	0.450	0.430	0.399
Digestible lysine, %	1.250	1.149	1.044
Digestible sulfur aminoacids, %	0.880	0.801	0.750
Digestible threonine, %	0.810	0.750	0.679
Digestible tryptophan, %	0.236	0.216	0.198
Digestible leucine, %	1.668	1.577	1.495
Digestible isoleucine, %	0.863	0.793	0.733
Digestible valine, %	0.923	0.856	0.797
Digestible arginine, %	1.329	1.217	1.122
Coline, mg/kg	1598.21	1594.54	1549.48
Na, %	0.221	0.194	0.184
Cl, %	0.268	0.312	0.301
K, %	0.917	0.847	0.786

<sup>1</sup>Replaced entirely by Essential® (1.5kg/ton) or partially by Enramycin (125 g/ton)  
<sup>2</sup> Vitamin premix (per kg): Vit. A 4,000 IU; Vit. D3 1,167 IU; Vit. E 10,000 IU; Vit. K3 1000 mg; Vit. B1 1,000 mg; Vit. B2 2,666.67 mg; Vit. B6 1,667 mg; Vit. B12 6,666.67 mcg; Niacin 13,333.33 mg; Pantothenic Acid 6,000 mg; Folic Acid 833.33 mg; Biotin 80,000 mcg; Antioxidant 22,200 mg. Mineral premix (per kg): Iron 23,333.33 ppm; Copper 2,666.67 ppm; Iodine 333.3 ppm; Zinc 33,333.33 ppm; Manganese 40,000 ppm; Selenium 80 ppm; Phytase 16,667 g/kg; Enzyme complex (xylanase, amylase and protease) 33.333 g/kg.

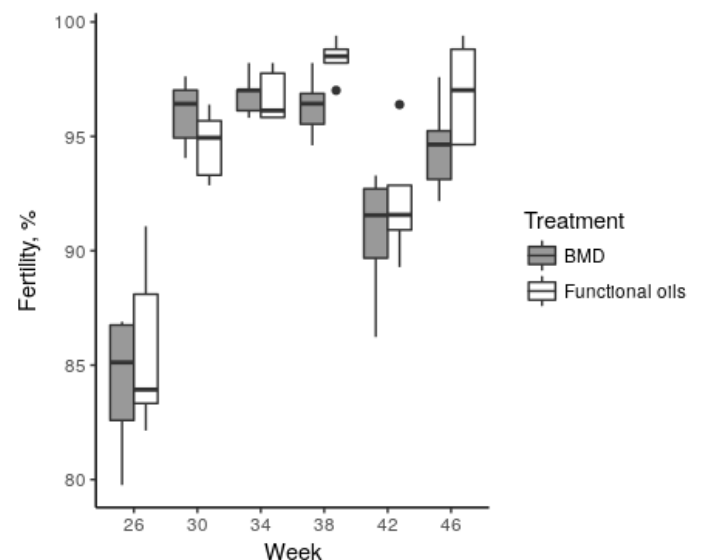
similar to what has previously been reported (de Avila *et al.*, 2003, Lewis and Gous, 2003, respectively). The average laying rate was 77.4 ± 13% across treatments for the whole length of the experiment. The hatching rate was analyzed the same way as laying rate and, again, there were no differences between the treatments, with an average rate of 73.2 ± 16%.

Fertility was not affected by the type of additive 93.73 ± 0.82%, however, there was a significant time-effect due to week ( $p < 0.01$ ), and a possible but not significant type of additive by week interaction ( $P$



**Figure 1** – Laying rates for breeders supplemented with either bacitracin methylene disalicylate (BMD) or functional oils (Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil) using a laying curve according to Yang *et al.*, 1989.

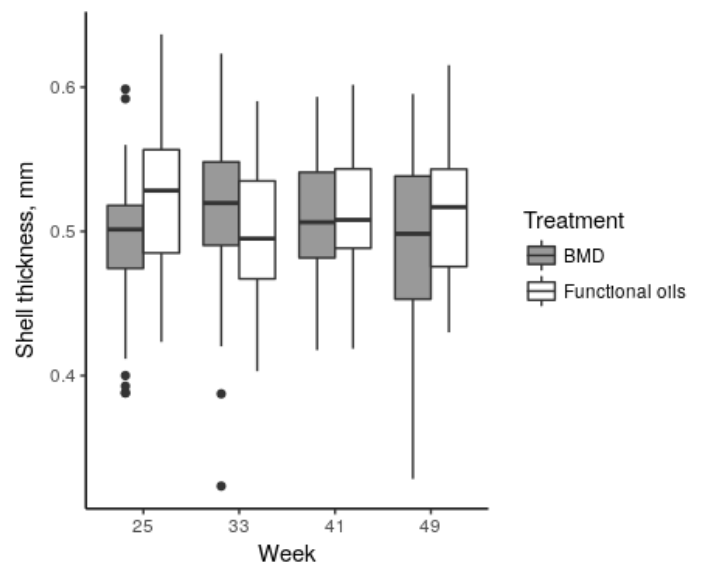
= 0.07), suggesting that fertility tended to increased by the functional oils at the beginning and the end of the experiment, but not during the peak production weeks (Figure 2). This may be related to a protective effect of the functional oils on the reproductive tract of the breeders by avoiding the lipid oxidation of the sperm (Breque *et al.*, 2003). Although the roosters were not supplemented with functional oils, the antioxidant effect on the sperm may have taken place in the uterovaginal sperm-host glands. Hens are able to store sperm in the uterovaginal sperm-host and infundibular glands for a long period and can maintain the production of fertile eggs for several weeks (Bakst *et al.*, 1994). However, the functional oils might have also had a direct and positive effect on the hens'



**Figure 2** – Fertility (%) of breeders supplemented with either bacitracin methylene disalicylate (BMD) or functional oils (Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil).



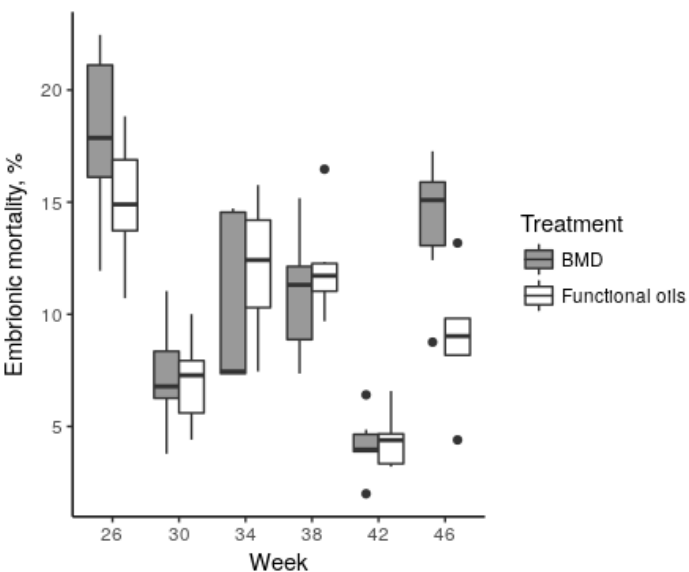
reproductive capabilities as the supplementation of functional oils also decreased embryonic mortality from 11.01% to 9.64% ( $p < 0.03$ ) when compared to BMD. The chorioallantois, which is the respiratory organ that forms a network of capillaries in the internal membrane of the eggshell, is formed during this period (Moran, 2007) and the antioxidant capabilities of the embryo might have improved by the supplementation of the functional oils. Weekly breeders mortality was not affected by type of additive and averaged  $0.13 \pm 0.05\%$  across treatments. The age of the breeders also affected the embryonic mortality ( $p < 0.01$ ), which was higher at the beginning of the experiment (Figure 3). The percentage of chicks/breeder/day was 56.08% for the BMD and 57.62% for the functional oils supplemented breeders, but this difference was not significant ( $p = 0.63$ ). As expected, chick weight increased with the age of the breeders ( $p < 0.01$ ) but was not affected by the type of additive and averaged 43.0 g, across treatments. The type of additive did not affect the percentage of either of contaminated or cracked eggs, being the average for these two parameters, 0.5 and 0.4%, respectively.



**Figure 4** – Eggshell thickness (MM) for breeders supplemented with either bacitracin methylene disalicylate (BMD) or functional oils (Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil).

## Experiment II

Performance results showed a maternal effect from 1 to 7 days of ages, where supplementation of breeders with functional oils did not result in different body weight gain (0.128 versus 0.132 kg;  $p = 0.08$ ) but resulted in increased feed conversion rate (1.272 versus 1.227 g:g;  $p = 0.02$ ). There was also an interaction between maternal and offspring effects ( $p = 0.01$ ), where the supplementation of functional oils increased the feed conversion rate in the offspring supplemented with Enramycin but decreased it when the offspring were supplemented with functional oils (Table 3). However, the differences in performance disappeared between days 8 and 21, being the average across treatments 0.807 kg, 1.124 kg, and 1.373 g:g for body weight gain, feed intake, and feed conversion rate, respectively (Table 3). As there were no differences in feed intake, only differences in either digestibility or metabolizability could explain the higher feed conversion during the first week of the experiment for the offspring of functional oils supplemented breeders. Antibiotic growth promoters have been shown to delay the development of the gut microbiota when compared to probiotics (Gao *et al.*, 2017), which may negatively affect performance. However, and unlike with antibiotic supplementation, functional oils supplementation has been shown to maintain the total number of bacteria in the intestinal microbiota (Moraes *et al.*, 2019), so one could expect improved weight gains after the first week of age might be due to a better development of the gut microbiota.



**Figure 3** – Embryonic mortality (%) of chicks from breeders supplemented with either bacitracin methylene disalicylate (BMD) or functional oils (Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil).

As expected, the age of the breeder increased all the studied egg characteristics ( $p < 0.01$ ) other than shell thickness (Figure 4). However, the effects of the treatments on the egg characteristics were numerically minimal, being the averages across treatments, 61.3 g, 18.5 g, 38.0 g, and 5.19 g for the weights of the egg, yolk, white, and shell, respectively, and 0.509 mm and 1.081 for the shell thickness and specific gravity, respectively.



**Table 3** – Offspring performance of bacitracin methylene disalicylate (BMD) or functional oils (FO: Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil) supplemented breeders, supplemented with either functional oils or Enramycin from 1 to 21 d.

Item	Maternal	Offspring						Maternal	p - value	
		BMD <sup>1</sup>		FO		Average			Offspring	Interaction
1 – 7 days		Mean	SD	Mean	SD	Mean	SD			
<b>BW gain, kg</b>										
	Enramycin	0.132	0.003	0.132	0.007	0.132	0.007			
	FO	0.125	0.009	0.130	0.008	0.128	0.009			
	Average	0.129	0.007	0.131	0.007	0.130	0.007	0.06	0.31	0.35
<b>Feed Intake, kg</b>										
	Enramycin	0.158	0.09	0.163	0.05	0.161	0.08			
	FO	0.163	0.11	0.159	0.06	0.161	0.09			
	Average	0.161	0.10	0.161	0.06	0.161	0.08	0.81	0.79	0.11
<b>FCR, g:g</b>										
	Enramycin	1.214	0.046	1.239	0.057	1.227	0.052			
	FO	1.309	0.052	1.234	0.055	1.272	0.065			
	Average	1.262	0.069	1.237	0.054	1.249	0.062	0.02	0.16	0.01
<b>8 – 21 days</b>										
<b>BW gain, kg</b>										
	Enramycin	0.807	0.034	0.797	0.030	0.802	0.022			
	FO	0.818	0.026	0.804	0.024	0.811	0.030			
	Average	0.813	0.027	0.801	0.027	0.807	0.026	0.59	0.18	0.81
<b>Feed Intake, kg</b>										
	Enramycin	1.130	0.050	1.106	0.046	1.118	0.048			
	FO	1.133	0.058	1.124	0.061	1.129	0.058			
	Average	1.132	0.052	1.115	0.053	1.124	0.053	0.85	0.36	0.67
<b>FCR, g:g</b>										
	Enramycin	1.372	0.035	1.379	0.031	1.375	0.032			
	FO	1.353	0.075	1.390	0.036	1.371	0.060			
	Average	1.363	0.058	1.384	0.033	1.373	0.048	0.80	0.19	0.35

<sup>1</sup>Bacitracin methylene disalicylate.

Although the offspring of functional oils supplemented breeders gained 86 g more than the offspring of BMD supplemented breeders, the difference was not significant ( $p=0.09$ ). Feed intake, feed conversion rate, and mortality were 4.447 kg, 1.565 g:g, and 3.75%, across treatments (Table 4) and were not different. Also, and although one limitation of this research was the lack of a control treatment without the supplementation of any growth promoter, either antibiotic or not, our findings show that under the conditions of the trials, the functional oils can successfully substitute antibiotic growth promoters both in breeder and broiler diets. The positive effects seen on the breeders tended to carry over to their offspring, as birds were numerically heavier ( $p=0.09$ ) at 42 days of age. This carry-over, if confirmed by other researches, would demonstrate an epigenetic effect, which could be attributed to the antioxidant capacity of functional oils, as positive epigenetic effects have been reported for antioxidants in other species. For example, antioxidant supplementation in sows and rats resulted in enhanced offspring growth performance

(Wan *et al.*, 2018) and improved offspring metabolic health (Zheng *et al.*, 2019).

In conclusion, broiler breeder supplementation with functional oils was, at least, as effective as BMD supplementation. In our trial, functional oils decreased embryonic mortality during the first 72 h of incubation and did not negatively affect any other reproductive parameter. This positive effect seemed to be carried over to the offspring, as birds from breeders supplemented with functional oils were numerically heavier at 42 d of age. When the offspring were supplemented with functional oils, the effects on the performance were not different from those attained with Enramycin supplementation, showing that functional oils can successfully substitute antibiotic growth promoters both in broiler breeders and broilers.

## REFERENCES

- Avila VS de, Penz Jr AM, Rosa PS, Brum PAR de, Guidoni AL, Ledur MC. Influence of feeding time on sexual maturity and carcass composition in female broiler breeders. *Brazilian Journal of Poultry Science* 2003;5(3):189-196.



**Table 4** – Offspring performance of bacitracin methylene disalicylate (BMD) or functional oils (FO: Essential, Oligo Basics Agroind. Ltda, Cascavel, Brazil) supplemented breeders, supplemented with either functional oils or Enramycin from 22 to 42 d and from 1 to 42 d.

Item	Maternal	Offspring						Maternal	<i>p</i> - value	
		BMD <sup>1</sup>		FO		Average			Offspring	Interaction
22 - 42 days		Mean	SD	Mean	SD	Mean	SD			
BW gain, kg	Enramycin	1.869	0.145	1.879	0.129	1.874	0.129	0.09	0.97	0.97
	FO	1.950	0.120	1.963	0.107	1.957	0.134			
	Average	1.910	0.156	1.921	0.118	1.915	0.136			
Feed Intake, kg	Enramycin	3.086	0.246	3.062	0.222	3.074	0.228	0.03	0.69	0.92
	FO	3.273	0.296	3.233	0.179	3.253	0.238			
	Average	3.179	0.281	3.148	0.215	3.163	0.265			
FCR, g:g	Enramycin	1.654	0.061	1.640	0.047	1.671	0.054	0.24	0.28	0.69
	FO	1.687	0.060	1.656	0.074	1.648	0.067			
	Average	1.647	0.061	1.672	0.061	1.659	0.061			
1 – 42 days BW gain, kg	Enramycin	2.808	0.152	2.808	0.140	2.808	0.142	0.09	0.97	0.97
	FO	2.893	0.181	2.897	0.114	2.895	0.147			
	Average	2.851	0.168	2.853	0.132	2.852	0.149			
Feed Intake, kg	Enramycin	4.374	0.297	4.330	0.264	4.352	0.274	0.06	0.62	0.96
	FO	4.569	0.353	4.516	0.235	4.542	0.292			
	Average	4.471	0.332	4.423	0.261	4.447	0.295			
FCR, g:g	Enramycin	1.560	0.044	1.584	0.026	1.572	0.036	0.15	0.37	0.87
	FO	1.549	0.053	1.568	0.051	1.559	0.051			
	Average	1.555	0.049	1.576	0.040	1.565	0.045			
Mortality, %	Enramycin	4.20	0.04	3.30	0.02	3.75	0.03	0.66	0.95	0.79
	FO	3.30	0.03	4.20	0.04	3.75	0.04			
	Average	3.75	0.04	3.75	0.03	3.75	0.03			

<sup>1</sup>Bacitracin methylene disalicylate.

Bakst MR, Wishart G, Brillard, JP. Oviducal sperm selection, transport and storage in poultry. *Poultry Science Reviews* 1994;5(5):117-143.

Bess F, Favero A, Vieira SL, Torrent J. The effects of functional oils on broiler diets of varying energy levels. *Journal of Applied Poultry Research* 2012;21:567–78.

Birendra M, Jha R. Oxidative stress in the poultry gut: potential challenges and interventions. *Frontiers in Veterinary Science* 2019;6:60.

Bozkurt M, Alçiçek A, Çabuk M, Küçükyılmaz K, Çatli AU. Effect of an herbal essential oil mixture on growth, laying traits, and egg hatching characteristics of broiler breeders. *Poultry Science* 2009;88(11):2368–2374.

Breque C, Surai, PF, Brillard, JP. Roles of antioxidants on prolonged storage of avian spermatozoa in vivo and in vitro. *Molecular Reproduction and Development* 2003;66(3):314- 323.

Efron B, Tibshirani R. An introduction to the bootstrap. Boca Raton: Chapman & Hall; 1993.

Gao P, Ma C, Sun Z, Wang L, Huang S, Su X, et al. Feed-additive probiotics accelerate yet antibiotics delay intestinal microbiota maturation in broiler chicken. *Microbiome* 2017;5:91.

Hu R, He Y, Arowolo MA, Wu S, He J. Polyphenols as potential attenuators of heat stress in poultry production. *Antioxidants* 2019;8(3):67.

Koedijk RM, Linde IB van de, Lamot DM, Hilbert M, Enting H. Antioxidants in broiler breeder diets can affect offspring performance. *Proceedings of the 26<sup>th</sup> Australian Poultry Science Symposium*; 2015 Feb 8-11; Sydney, Australia. New South Wales: Poultry Research Foundation; 2015. p.194-197.

Lewis PD, Gous, RM. Constant and changing photoperiods in the laying period for broiler breeders allows normal or accelerated growth during the rearing period. *Poultry Science* 2006;85:321–325.

Moraes PO, Andretta I, Cardinal KM, Ceron M, Vilella L, Borille R, et al. Effect of functional oils on the immune response of broilers challenged with *Eimeria* spp. *Animal* 2019;13(10):2190-2198.

Moran Jr. ET. Nutrition of the developing embryo and hatchling. *Poultry Science* 2007;86(5):1043–1049.

Murakami AE, Eyng C, Torrent J. Effects of functional oils on coccidiosis and apparent metabolizable energy in broiler chickens. *Asian-Australasian Journal of Animal Science* 2014;27(7):981-989.

Novak AF, Clark GC, Dupuy HP. Antimicrobial activity of some ricinoleic and oleic acid derivatives. *Journal of the American Oil Chemists' Society* 1961;38:321-324.





- Pappas AC, Acamovic T, Sparks NHC, Surai PF, McDevitt RM. Effects of supplementing broiler breeder diets with organic selenium and polyunsaturated fatty acids on egg quality during storage. *Poultry Science* 2005;84(6):865–874.
- R: The R Project for Statistical Computing [cited 2018 Oct 12]. Available from: [www.r-project.org/](http://www.r-project.org/).
- Rosa AP, Scher A, Sorbara JOB, Boemo LS, Forgiarini J, Londero A. Effects of canthaxanthin on the productive and reproductive performance of broiler breeders. *Poultry Science* 2012;91(3):660–666.
- Surai PF, Kochish II, Romanov MN, Griffin DK. Nutritional modulation of the antioxidant capacities in poultry: the case of vitamin E. *Poultry Science* 2019;98(9):4030-4041.
- Torrent J, Arce Menocal J, López Coello C, Ávila González E. Effects of functional oils on performance and carcass characteristics of broilers under two ambient temperatures. *Poultry Science* 2019;98(11):5855-5861.
- Trevisan MTS, Pfundstein B, Haubner R, Würtele G, Spiegelhalter B, Bartsch H, et al. Characterization of alkyl phenols in cashew (*Anacardium occidentale*) products and assay of their antioxidant capacity. *Food and Chemical Toxicology* 2005;44(2):188-197.
- Vieira C, Fetzer S, Sauer SK, Evangelista S, Averbek B, Kress M, et al. Pro- and anti-inflammatory actions of ricinoleic acid: similarities and differences with capsaicin. *Naunyn-Schmiedeberg's Archives of Pharmacology* 2001;364:87–95.
- , McMillan, I. Wan J, Xu Q, He J. Maternal chitosan oligosaccharide supplementation during late gestation and lactation affects offspring growth. *Italian Journal of Animal Science* 2018;17:4:994-1000.
- Yang N, Wu C, McMillan, I. New mathematical model of poultry egg production. *Poultry Science* 1989;68(4):476-481.
- Zheng S, Feng Q, Cheng J, Zheng J. Maternal resveratrol consumption and its programming effects on metabolic health in offspring mechanisms and potential implications. *Bioscience Reports* 2018;38(2):BSR20171741.

