FULL ARTICLE

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Effect of exogenous emulsifier and different fat sources on the performance, carcass characteristics, nutrient digestibility, and serum lipid profile of broiler chickens

Efeito de emulsificante exógeno e diferentes fontes de gordura no desempenho, características de carcaça e digestibilidade de nutriente e perfil lipídico sérico em frangos de corte

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ABSTRACT

A study was conducted to evaluate the effect of an emulsifier on reduced-energy diets using two fat sources for broilers. The study was designed as a 2 x 3 factorial arrangement of treatments. The first factor was 2 fat sources (poultry fat or beef tallow). The second factor was a basal diet with the recommended energy levels, a diet with a 0.83 MJ/kg of energy reduction, and a diet with an energy reduction and inclusion of 1 g emulsifier/kg of diet. The emulsifier used in this study was composed of soy lecithin and polyethylene glycol ricinoleate. The emulsifier increased apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen balance (AMEn) in beef tallow diets compared to energy-reduced diets (P<0.001). Broilers fed poultry fat had higher weights and weight gains at 35 and 42 d of age (p=0.001), and they had higher daily deposition of fat in the carcass (P = 0.025) when compared to diets with beef tallow. The inclusion of emulsifiers in broiler diets improves AME and AMEn but did not affect the energy reduction diets, which resulted in reduced performance, decreasing daily fat deposition, but without effects on serum lipid profile in broilers.

Keywords: Broiler nutrition. Soy lecithin. Fat sources. Surfactant.

RESUMO

Um estudo foi conduzido para avaliar o efeito de um emulsificante em dietas com baixo teor de energia usando duas fontes de gordura para frangos de corte. O estudo foi delineado em arranjo fatorial 2 x 3 de tratamentos, o primeiro fator foi 2 fontes de gordura (gordura de frango ou sebo bovino) e o segundo fator uma dieta basal com os níveis de energia recomendados, uma dieta com 0,83 MJ / kg de redução de energia e uma dieta com redução de energia e inclusão de 1 g de emulsionante / kg de dieta (composto de lecitina de soja e ricinoleato de polietilenoglicol). O emulsificante aumentou a energia metabolizável aparente (EMA) e a energia metabolizável aparente corrigida para o balanço de nitrogênio (EMAn) em dietas com sebo bovino em comparação com dietas com redução de energia (P <0,001). Frangos de corte alimentados com gordura de frango apresentam maiores pesos e ganhos de peso aos 35 e 42 dias de idade (p=0,001), e maior deposição diária de gordura na carcaça (P=0,025) quando comparados às dietas com sebo bovino. O emulsificante incluído nas dietas de frangos de corte melhora a EMA e EMAn, mas não supre a redução energética, causando efeitos negativos no desempenho, diminuindo a deposição diária de gordura, mas sem efeitos no perfil lipídico sérico em frangos de corte.

Palavras-chaves: Nutrição de frango. Lecitina de soja. Fontes de gordura. Surfactantes.

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Introduction

The inclusion of oils and fats in broiler diets is recommended to increase feed energy density, thereby improving the energy efficiency (National Research Council, 1994), growth rate, and nutrient utilization of feed (Junqueira et al., 2005), reducing the dust, and particle separation, increasing the absorption of fat-soluble vitamins and lubricating the grinding equipment (Ravindran et al., 2016). These sources often have been used as ingredients in animal feed for energy supply animals (Classen, 2017).

Fat animal sources have been used more frequently since with the increase in animal processing, the production of oils and fats and their use in animal feed is considered sustainable (Ferreira et al., 2018). However, fats of different species bring different characteristics to these ingredients, with particular emphasis on lower energy use when compared to vegetable oils (Fascina et al., 2009; Junqueira et al., 2005). Poultry fat and beef tallow are interesting examples of products for the utilization of animal fats and oil to enhance the energy use from fat sources.

Lipids are insoluble in water, do not solubilize in the aqueous phase of the gastrointestinal tract, and need to be emulsified before they can be hydrolyzed by lipase (Silva et al., 2014). Studies on the use of exogenous emulsifiers in poultry diets demonstrate their potential to improve animal performance; improve the use of metabolizable energy in the diet (Hu et al., 2012); improve feed conversion (Papadopoulos et al., 2014), increase fat utilization, increase body fat deposition and reduce abdominal fat deposition (Zhang et al., 2010) in conventional diets; and to increase the feed shelf-life by reducing the peroxide index (Liu et al., 2013). The objective of this study was to evaluate the inclusion of an exogenous emulsifier and two fat sources (poultry fat and beef tallow) on the performance, nutrient digestibility, carcass composition, and serum lipid profile of broilers.

Materials and Methods

All the experimental procedures using animals were previously approved by the Committee on Ethics in Animal Use (CEUA/Federal Rural University of Amazonia, protocol 007/2013). Two experiments were conducted, the first to evaluate the digestibility of nutrients, and the second to evaluate the performance of the birds.

Experimental diets

The nutritional program had a split start phase from 0 to 21 days, growing from 21 to 35 days, and finishing from 35 to 42 days of age (Table 1). The diets were formulated to be isonutritive, except for gross energy values, which were adjusted according to the treatment. The treatments were defined by diets with the inclusion of poultry fat (PF) or beef tallow (BT), and three energy levels: a basal diet with energy levels recommended by Rostagno (2011), a diet with a 0.83 MJ/kg energy reduction and a diet with a reduction in energy and inclusion of 1 g/kg emulsifier (emul). The emulsifier Liposorb® (Polchen-Innovative Solution) contained 500 g/kg soybean lecithin (phosphatidylcholine and lysophosphatidylcholine) and 500 g/kg polyethylene glycol ricinoleate, following the manufacturer's recommendation. Silica sand was used as an inert ingredient in the diets.

Nutrient digestibility

A total of 336 male broilers, Cobb-500, were distributed in metabolic cages in six treatments, with seven replicates each. The diets of the initial phase (0 to 21 days) were used, as established in the nutritional program. From five days of adaptation to 18 days of age, excreta were collected for five days by the total collection method (Sakomura & Rostagno, 2016). After total collection, the samples were pre-dried in a forced ventilation oven at 55° C for 72 h to determine the chemical compositions.

Performance and carcass

A total of 1,248 1-day-old Cobb-500 male chicks, with mean weights of 39.11±1.09 g, distributed in six treatments with eight replicates each, were used in an experimental box with 26 birds. The weighing of the birds occurred at 21, 35, and 42 days of age to determine the average weight, daily weight gain, feed intake, feed conversion, viability, and energy utilization efficiency for gain. Viability was

Table 1 – Composition and nutrient content of diets, according to the age of birds

Item (g/kg)	Start (d 0 to 21)				Growing (d 21 to 35)				Finishing (d 35 to 42)			
	Poultry fat		Beef tallow		Poultry fat		Beef tallow		Poultry fat		Beef tallow	
	Basal	Reduction	Basal	Reduction	Basal	Reduction	Basal	Reduction	Basal	Reduction	Basal	Reduction
Ingredients												
Corn	550.8	555.1	534.4	561.5	580.1	612.1	559.9	618.5	628.5	652.4	609.4	658.8
Soybean meal	362.4	361.6	365.4	360.5	326.8	321.1	330.5	319.9	287.0	282.7	290.5	281.6
Poultry fat	39.5	15.0	0.0	0.0	49.0	15.0	0.0	0.0	46.3	15.0	0.0	0.0
Beef tallow	0.0	0.0	52.9	15.0	0.0	0.0	65.7	15.0	0.0	0.0	62.0	15.0
Dicalcium phosphate	15.1	15.1	15.1	15.1	13.0	13.0	13.1	13.0	11.0	11.0	11.0	11.0
Limestone	8.7	8.7	8.7	8.7	8.3	8.3	8.3	8.4	7.4	7.4	7.4	7.4
Sodium chloride	2.3	2.3	2.3	2.3	2.2	2.1	2.2	2.1	2.0	2.0	2.0	2.0
DL-methionine (98%)	3.2	3.2	3.2	3.2	3.0	2.9	3.0	2.9	2.7	2.7	2.7	2.7
L-lysine (99%)	2.4	2.4	2.3	2.4	2.4	2.4	2.2	2.5	2.6	2.7	2.6	2.7
Threonine (98%)	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8
Inert	5.1	26.1	5.1	20.8	5.0	12.8	4.9	7.4	5.1	16.7	5.0	11.2
Sodium bicarbonate	3.7	3.7	3.7	3.7	3.5	3.6	3.5	3.6	3.6	3.6	3.6	3.6
Premix[a]	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	3.0	3.0	3.0	3.0
Calculated nutrient level (as-fed basis)												
AME (MJ/kg)	12.76	11.92	12.76	11.92	13.17	12.34	13.17	12.34	13.38	12.55	13.38	12.55
Crude protein (g/kg)	212.0	212.0	212.0	212.0	198.0	198.0	198.0	198.0	184.0	184.0	184.0	184.0
Ca (g/kg)	8.4	8.4	8.4	8.4	7.6	7.6	7.6	7.6	6.6	6.6	6.6	6.6
Available P (g/kg)	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.1	3.1	3.1	3.1
Lysine (g/kg)	12.2	12.2	12.2	12.2	11.3	11.3	11.3	11.3	10.6	10.6	10.6	10.6
Methionine + cysteine (g/kg)	8.8	8.8	8.8	8.8	8.3	8.3	8.3	8.3	7.7	7.7	7.7	7.7

[a]Provides per kg diet: 16.66 IU vitamin A; 2.50 mg thiamine; 20 mg riboflavin; 8 mg vitamin B2; 25 mg pyridoxine; 33 UI vitamin D3; 25 IU vitamin E; 4.1 mg menadione; 0.80 mg biotin; 510.6 mg choline chloride; 58.33 mg niacin; 10 mg folic acid; 17.17 mg calcium pantothenate; 0.16 mg Co; 60 mg Cu; 49 mg Fe; 1.66 I; 1 g Mg; 30 mg Se; 45 mg Zn; 50 mg halquinol; 73 mg narasina; 73 mg nicarbazina.

calculated by subtracting the number of dead birds from the total number of birds in each experimental unit and transforming it to a percentage (%). At 42 days of age, 16 birds per treatment with weights closest to the average of the respective treatment, based on average repetition weight, with a 5% confidence interval, were slaughtered, plucked, and eviscerated. The carcass yield was calculated by the ratio of the weight of the hot gutted carcass to the slaughter weight.

Chemical analyses

Diet, carcass, and fecal samples were analyzed for dry matter (DM, method 930.15; Association of Official Analytical Chemists, 2007), crude protein (CP, method 990.03; Association of Official Analytical Chemists, 2007), and extract ether (EE, method 920.39; Association of Official Analytical Chemists, 2007). The gross energy (GE) in the diets and feces was determined by an automatic isoperibol calorimeter with an oxygen bomb (IKA Calorimeter System C 200; IKA Works, Wilmington, NC, USA). For the carcass composition, all 16 eviscerated carcasses were processed in a cutter and then lyophilized to determine the dry matter.

Calculations

The apparent metabolizable energy (AME) was calculated using the following formula, with appropriate corrections made for differences in the DM content:

$$\text{AME (MJ/kg diet)} = \left[(\text{feed intake x GEdiet}) - (\text{excreta output x GE excreta})\right] / \text{feed intake} \quad (1)$$

where GEdiet is the GE content in the diet and GEexcreta is the GE content in the excreta. The N-corrected AME (AMEn) values were calculated by correcting for the N equilibrium (zero retention) by using a factor of 36.52 MJ/g N retained in the body (Hill & Anderson, 1958). The apparent N retention coefficient was calculated as follows:

$$\text{Retention coefficient} = \left[(\text{Feed intake x Ndiet}) - (\text{Excreta output x Nexcreta})\right] / \left((\text{Feed intake x Ndiet})\right) \quad (2)$$

The energy values are expressed in MJ/kg of the sample, and feed intake and excreta output in kg/experimental unit. Nitrogen was measured in g/kg of the sample, in dry matter.

The eviscerated carcasses, without feet and heads, were sawn in half, milled in a conventional meat grinder, and dried by freeze-drying for 72 h. The calculation of fat and protein deposition in the carcass was performed by the relation between the protein deposition or ether extract/carcass (g/kg) weight/age of the birds.

Serum measurement

Blood serum samples (2 broilers/pen) were collected at 21, 35, and 42 d old, serum was obtained by centrifugation of the coagulated blood, as were the serum total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol

(HDL-C), and low-density lipoprotein cholesterol (LDL-C), which were measured by colorimetric enzymatic methods using commercially available laboratory kits from Labtest Diagnostica SA, Lagoa Santa, MG, Brazil. In an automated biochemical analyzer, Mindray BS-120 (Mindray, China), very low-density lipoprotein (VLDL-C) was calculated by dividing TG content by five (Friedewald et al., 1972), expressed in mmol/L.

Statistical analysis

The data were analyzed as a 2 × 3 factorial arrangement of treatments in a completely randomized design. The first factor was 2 fat sources (poultry fat or beef tallow). The second factor was 3 diets, basal diet, energy-reduced diet, and the inclusion of an emulsifier. The replicate cage in performance (8 cages) and nutrient digestibility (7 cages) or birds on the carcass characteristics (16 birds/treatments) and lipogram series (16 birds/treatments) were considered as the experimental unit for analyzing the obtained data. Data were subjected to analysis of variance using the General Linear Models procedures, which were performed using the SAS software (SAS Institute Inc, 2014). All data are presented as tables including the least-square means and standard error of the means and differences between treatment means were evaluated by Tukey's test. The results are considered statistically significant if P ≤ 0.05.

Results

Nutrient digestibility

No effect of treatments was observed on the digestibility of dry matter and crude protein for any of the tested factors (Table 2). There was a significant interaction effect of the source and fat diets tested for digestibility of the ether extract (P <0.001), AME (P = 0.014), and AMEn (P = 0.006). The digestibility of ether extract from reduced-energy and reduced-energy diets with emulsifiers did not differ between the independent sources of fat tested. Regardless of the fat source, the basal diet had a higher digestibility of ether extract when compared to reduced-energy diets with an emulsifier. The emulsifier increased AME and AMEn in beef tallow diets compared to energy-reduced diets.

Performance

Performance results are shown in Table 3. Fat sources influenced average weight and average weight gain. The broilers fed poultry fat had greater weights and weight gains at 35 and 42 days than broilers fed with tallow beef. During the initial phase (0 to 21 d-old), diets with reduced-energy and reduced-energy diets plus emulsifier did not change body weight and body weight gain, but improved gain: feed due to reduced feed intake.

Yield and carcass composition

The results of the composition of the yield and carcass composition are presented in Table 4. Higher content of crude protein in the eviscerated carcass (P = 0.009), and lower daily deposition ether extract (P = 0.031) were observed in broilers fed the diet with emulsifier when compared to the basal diet. Broilers fed a diet that had poultry fat had a higher daily deposition in the ether extract carcass (P = 0.025) compared to birds fed beef tallow.

Lipid profile

There was no interaction between the fat source and the diets evaluated for the broiler's serum lipid profile at the different ages studied (Table 5). The results of VLDL and TG at 42 days of age were lower for broilers fed the basal diet when compared to the reduced diet, while the diets with emulsifiers did not differ from the others.

Discussion

The present study was conducted to investigate the effect of diets with different fat sources and the inclusion of emulsifiers in broiler diets. The fat sources tested

Table 2 – Apparent digestibility of dry matter, ether extract, crude protein, and metabolizable energy evaluated from 19 to 24 d of the age of broilers

Item	Fat:	Poultry fat			Beef tallow			SEM	*P*-value		
	Diets:	Basal	Reduction	Emulsifier	Basal	Reduction	Emulsifier		Fat	Diets	Fat x Diets
Digestibility (mg/kg)											
Dry matter		74.81	72.56	74.40	73.99	74.26	73.07	0.453	0.873	0.676	0.374
Crude protein		69.71	67.08	71.03	72.09	71.12	67.82	0.847	0.534	0.660	0.205
Ether extract		85.15[c]	82.48[b]	76.37[b]	88.85[a]	76.11[ab]	78.58[b]	0.792	<0.001	0.197	<0.001
AME (MJ/Kg)		14.15 [ab]	13.39 [dc]	13.27 [dc]	14.41[a]	13.01[abd]	13.94[c]	0.103	0.189	<0.001	0.014
AMEn (MJ/kg)		13.29[a]	12.55[bc]	12.42[bc]	13.49[a]	12.14[ab]	13.08[c]	0.098	0.249	<0.001	0.006

[a-c] Means within a line that do not share a common superscript letter are different (P < 0.05). SEM: standard error of the mean.

Table 3 – Effect of emulsifier supplementation on the growth performance of broilers

Item	Fat		Diet			SEM	*P*-value		
	Poultry fat	Beef tallow	Basal	Reduction	Emulsifier		Fat	Diets	Fat x Diets
Body weight (g/bird)									
21 d-old	1,011.52	986.24	1,006.60	1,004.93	985.11	7.47	0.079	0.388	0.057
35 d-old	2,161.15[a]	2,077.04[b]	2,173.31[a]	2,107.66[ab]	2,076.34[b]	14.52	0.001	0.007	0.330
42 d-old	2,679.55[a]	2,575.68[b]	2,708.77[a]	2,603.08[b]	2,571.00 [b]	18.41	0.001	0.001	0.739
Body weight gain (g/bird)									
0 to 21 d-old	972.35	947.14	965.84	967.46	945.95	7.47	0.079	0.387	0.057
0 to 35 d-old	2,121.99[a]	2,037.95[b]	2,134.21[a]	2,068.52[ab]	2,037.18[b]	14.54	0.001	0.007	0.330
0 to 42 d-old	2,640.38[a]	2,536.58[b]	2,669.68[a]	2,563.93[b]	2,531.84[b]	18.41	0.001	0.001	0.739
Feed intake (g/bird)									
0 to 21 d-old	1,147.60	1,130.69	1,236.33[a]	1,128.91[b]	1,052.21[b]	17.60	0.528	<.001	0.053
0 to 35 d-old	3,058.05	3,030.40	3,082.18	3,040.14	3,010.37	25.43	0.597	0.530	0.486
0 to 42 d-old	4,399.51	4,344.54	4,421.09	4,383.57	4,311.42	39.34	0.493	0.525	0.357
Gain:feed (g/g)									
0 to 21 d-old	1.18	1.19	1.28[a]	1.16[b]	1.11[b]	0.01	0.717	<.001	0.534
0 to 35 d-old	1.44	1.49	1.44	1.47	1.47	0.01	0.057	0.512	0.320
0 to 42 d-old	1.66	1.71	1.65	1.71	1.70	0.01	0.118	0.254	0.653
Viability (%)									
0 to 21 d-old	95.94	97.26	95.83	96.86	97.11	0.65	0.333	0.712	0.561
0 to 35 d-old	92.78	94.39	90.38	94.95	95.43	1.07	0.452	0.111	0.472
0 to 42 d-old	94.24	92.43	90.64	95.88	93.49	1.04	0.360	0.105	0.097

[a-c] Means within a line that do not share a common superscript letter are different ($P < 0.05$). SEM: standard error of the mean.

Table 4 – Effect of emulsifier supplementation on the carcass characteristics of broilers

Item	Fat		Diet			SEM[1]	*P*-value		
	Poultry fat	Beef tallow	Basal	Reduction	Emulsifier		Fat	Diets	Fat x Diets
Carcass yield	87.14	86.93	86.83	87.40	86.87	0.22	0.643	0.536	0.912
Composition eviscerated carcass (mg/kg)									
Dry matter	30.04	29.60	30.58	29.49	29.39	0.28	0.448	0.168	0.552
Crude protein	56.08	58.31	54.78[a]	57.91[ab]	58.93[b]	0.61	0.058	0.009	0.147
Ether extract	31.79	30.28	33.43	30.06	29.62	0.72	0.284	0.053	0.110
Deposition on carcass (g/day/bird)									
Crude protein	34.94	35.55	35.20	34.60	35.94	0.57	0.593	0.635	0.076
Ether extract	20.86[a]	18.48[b]	21.46[a]	19.46[ab]	18.09[b]	0.55	0.025	0.031	0.077

[a-c] Means within a line that do not share a common superscript letter are different ($P < 0.05$). SEM: standard error of the mean.

(poultry fat and beef tallow) had no effect or interaction with the emulsifier in the dry matter and crude protein digestibility, gain feed, viability, carcass yield, composition eviscerated carcass, deposition carcass, and lipid profile. Regarding the effects of the fat type in broiler diets, previous studies indicated that the source of fat does not influence the deposition of other nutrients in the animal carcass (Kanakri et al., 2017, 2018; Maniila et al., 1999) or the dry matter digestibility (Oliveira et al., 2019), but influence the composition of fatty acids (Gaiotto et al., 2000). Studies conducted by (Rodriguez-Sanchez et al., 2019) reported that the broiler's age influences the digestibility with an absorption restriction in broilers at the starter phase, regardless of the tested fat source. Our study showed that even though the effect in the initial stage was observed, it allowed greater weight gain of birds fed poultry fat in the following stages (growing and finishing).

On the other hand, diets with beef tallow present lower digestibility of the ether extract and, consequently, lower AME and AMEn (Scaife et al., 1994; Tancharoenrat et al., 2013). However, the basal diet with beef tallow had greater digestibility of ether extract, when compared to the basal diet with poultry fat. A possible explanation for these results is that the diet's total ether extract originated not only from the added fat but also from the remaining ingredients, such as corn and soybean meal, which allowed a lower ratio of saturated: unsaturated, improving the beef tallow absorption, as reported by Zhang et al. (2011).

The observed interaction between the source of fat and the inclusion of an emulsifier was previously mentioned

Table 5 – Effect of emulsifier supplementation on the serum lipid profile of broilers

Item	Fat		Diet			SEM	*P*-value		
	Poultry fat	Beef tallow	Basal	Reduction	Emulsifier		Fat	Diets	Fat x Diets
Cholesterol (mmol / L)									
21 d-old	3.13	3.10	3.15	3.12	3.07	0.07	0.797	0.924	0.313
35 d-old	3.20	3.04	3.04	3.10	3.23	0.06	0.306	0.727	0.686
42 d-old	2.83	2.63	2.64	2.86	2.69	0.06	0.129	0.368	0.199
HDL-C (mmol / L)									
21 d-old	2.32	2.16	2.17	2.29	2.25	0.04	0.082	0.252	0.445
35 d-old	2.15	2.19	2.15	2.03	2.32	0.06	0.726	0.182	0.562
42 d-old	2.03	1.93	1.98	2.04	1.92	0.03	0.203	0.812	0.043
LDL-C (mmol / L)									
21 d-old	0.40	0.40	0.39	0.41	0.40	0.01	0.901	0.700	0.149
35 d-old	0.74	0.72	0.76	0.68	0.76	0.03	0.822	0.557	0.756
42 d-old	0.60	0.60	0.57	0.61	0.62	0.02	0.969	0.714	0.708
VLDL-C (mmol / L)									
21 d-old	0.16	0.17	0.18	0.18	0.14	0.01	0.738	0.050	0.071
35 d-old	0.16	0.16	0.16	0.16	0.16	0.01	0.740	0.955	0.628
42 d-old	0.13	0.14	0.12[a]	0.16[b]	0.14[ab]	0.01	0.171	0.016	0.241
TG (mmol / L)									
21 d-old	0.83	0.89	0.93	0.91	0.73	0.03	0.410	0.051	0.070
35 d-old	0.80	0.82	0.83	0.81	0.81	0.03	0.741	0.957	0.622
42 d-old	0.66	0.74	0.60[a]	0.81[b]	0.70[ab]	0.03	0.163	0.029	0.086

[a-c] Means within a line that do not share a common superscript letter are different ($P < 0.05$). SEM: standard error of the mean. HDL-C: high-density lipoprotein cholesterol. LDL-C: low-density lipoprotein cholesterol. VLDL-C: Very low-density lipoprotein. TG: Triglyceride.

by (Guerreiro Neto et al., 2011), for the ether extract digestibility. Contradictorily, in this study, the emulsifier did not improve the digestibility, and on the other hand, the planned energy reduction for the diets with beef tallow modified AME and AMEn, and the emulsifier increased 0.9 MJ/kg an AME and AMEn in the energy-reduced diets with an emulsifier. Other studies reported that the improvement in energy harnessing with the use of emulsifiers occurs due to the greater digestibility of the ether extract. According to Santos et al. (2017), the beef tallow had higher digestibility for pigs when the animals received emulsifier supplementation, therefore increasing the diet's energy harnessing.

There was no interaction between fat sources and diets on the digestibility evaluations. In the initial stage (0 to 21 d-old) the birds had lower feed consumption with the energy reduction and emulsifier if compared with the basal diet, with no effect on the average weight gain and average weight, which resulted in better feed conversion. The feed intake was lower for diets with reduced energy and for reduced energy with an emulsifier. In these last two, there was a better feed conversion, indicating improvement in the efficiency of the use of the emulsifier in diets during the initial phase. One likely explanation for the increased average weight gain and improved feed conversion in broilers, observed during the starter period, is the lower production of lipase during the starter phase (Upadhaya et al., 2018).

In the following stages (growing and finishing), the average weight was lower on the diets with energy reduction, with or without emulsifier. According to Cho et al. (2012), the reduction in the diet's energy density (0.6 MJ/kg AME) reduced the performance and can be compensated by the addition of exogenous emulsifiers, with no reduction on growth parameters, an effect that was not observed in this study. The energy reduction could have been balanced by the animal with the increase of feed consumption in the growth and finishing stages, but the physical restriction on the broiler chickens' gastrointestinal tract was attributed to the low capacity of diet ingestion adjustment, even with the reduction of metabolizable energy (Wang et al., 2016).

Previous studies about exogenous emulsifiers used on bird diets are widely inconsistent. For example, (Aguilar et al., 2013; Zhang et al., 2011) reported that the use of exogenous emulsifiers significantly increases the body weight gain in broiler chickens since the initial stage (1 to 21 d-old), as in this stage, according to (Huang et al., 2007), the low enzyme production can be provided by the use of exogenous emulsifiers. Nevertheless, (Polycarpo et al., 2016; Roy et al., 2010; Zaefarian et al., 2015; Zampiga et al., 2016) did not observe the effect of emulsifier use on birds' performance. According to Jansen et al. (2015), the level of saturation of the studied lipid source could explain these effects. However, the emulsifier used in our study has soybean lecithin and polyethylene glycol ricinoleate (PERG) in its composition.

According to Tan et al. (2016), PERG is the highest on diets with high-unsaturated fat concentration, and soy lecithin improves the digestibility of more saturated fat. Upadhaya et al. (2018) found that the combination of emulsifiers is beneficial for increasing fat digestibility. There was no influence of the source of fat or emulsifier on the carcass productivity, which is consistent with other results (Andreotti et al., 2004; Ferreira et al., 2008; Guerreiro Neto et al., 2011; Lara et al., 2005, 2006), which also did not observe differences on the broiler chicken carcass fed with different sources of fat or emulsifier. The deposition of protein on the carcass was increased by the addition of an emulsifier, and the daily deposition of ether extract was reduced. This result might be related to the broiler's lower average weight and average weight gain, as the diets with emulsifiers presented lower energy and lower fat addition, and the added emulsifier was not able to counteract this reduction.

In none of the evaluated ages, the emulsifier, the source of fat, and the level of energy present effect on TC, HDL-C, or LDL-C, which are similar to the results of Aghdam Shahriar et al. (2007) and Ali et al. (2017). Other studies suggest that soy lecithin presents a hypo-cholesterol effect (Wilson et al., 1998), because this effect is related to the cholesterol absorption inhibition in the small intestine, as described by Iwata et al. (1992) and Spilburg et al. (2003). The concentration of emulsifier tested in this study may not have affected the evaluated cholesterol index, according to the results of Attia et al. (2018), which described that soy lecithin inclusions superior to 10 g/kg on the diet reduce the concentration of LDL-C and total cholesterol.

Conclusion

The inclusion of emulsifier containing 500 g/kg soybean lecithin (phosphatidylcholine and lysophosphatidylcholine), and 500 g/kg polyethylene glycol ricinoleate, at 1g/kg of feed in chicken diets improves AME and AMEn, but did not affect the energy reduction diets, which resulted in reduced performance, decreased daily fat deposition, and no effects on serum lipid profile in broilers.

Conflict of Interest

The authors have no conflict of interest to declare for this study.

Ethics Statement

All the experimental procedures using animals were previously approved by the Committee on Ethics in Animal Use (CEUA/Federal Rural University of Amazonia, protocol 007/2013).

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